EARLY CARADOC TRILOBITES OF EASTERN IRELAND AND THEIR PALAEOGEOGRAPHICAL SIGNIFICANCE

by M. ROMANO *and* A. W. OWEN

ABSTRACT. Twenty-five trilobite species belonging to twenty-three genera are recorded from the Caradoc Knockerk Formation of the Grangegeeth area, eastern Ireland. *Arthrorhachis knockerkensis* and *Birmanites salteri* are new, while *Barrandia* sp. and *Flexicalymene* sp. possibly represent new species. The faunas occur predominantly in the lower parts of the Knockerk House Sandstones Member and younger Brickwork's Quarry Shales Member. The older fauna is of early Caradoc age and shows affinities with species from the Balclatchie and Lower Ardwell groups at Girvan. The younger trilobite fauna and associated graptolites are indicative of the *Climacograptus peltifer* Biozone (possibly Harnagian). The Laurentian/Scoto-Appalachian affinities of the Grangegeeth Caradoc faunas indicate that the Grangegeeth terrane was closest to Laurentia during the early Caradoc and that the final Iapetus Suture line must lie to the south of the Grangegeeth terrane.

THE Ordovician shelly faunas of eastern Ireland have become increasingly important in determining the position of the Iapetus Suture in this complex sector of the Caledonide Orogen. In particular, the area around Grangegeeth (Text-fig. 1) is sited near the proposed line of the suture, and an understanding of the affinities of the faunas is vital to unravelling the tectonic history of this region.

The first detailed description of the Ordovician sequence and faunas of the area between Slane, Co. Meath, and Collon, Co. Louth, in eastern central Ireland was by J. C. Harper (1952). In this account, Harper listed eight trilobite species, and figured five, from his 'Upper Tuffs and Shales (including the brown shales of Mellifont)'. The area was remapped by Romano for an undergraduate dissertation, during which a rich fauna with abundant trilobites was discovered within Harper's unit. These trilobites were recorded by Brenchley *et al.* (1967) who listed eleven species and figured four. These authors ascribed the trilobite fauna to the *Climacograptus peltifer* Biozone on account of the associated graptolites, and suggested that it may be of Harnagian age. Harper and Romano (1967) described a new trinucleid trilobite, *Decordinaspis bispinosa*, from that fauna. Romano (1970) proposed the name 'Brickwork's Quarry Shales' for this richly fossiliferous unit, and defined it as the third member of the Knockerk Formation; nineteen trilobite species were described and figured from it. The two lower members also yield trilobites, though less abundantly.

In a re-appraisal of some Ordovician successions from eastern Ireland, Brenchley *et al.* (1977) discussed their correlation with particular reference to dating the main episodes of volcanicity. The affinity of the Brickwork's Quarry Shales trilobite fauna to that from the Balclatchie Mudstones of Scotland, was noted. Romano (1980) formally described the Ordovician lithostratigraphy of the Slane-Collon area and listed eight trilobite species from the Knockerk House Sandstones Member, three from the Knockerk House Shales Member and nineteen from the Brickwork's Quarry Shales Member.

The present paper is the first formal systematic work on the trilobite faunas and sets the trilobites in a palaeobiogeographical context. In doing so, it places important constraints on the interpretation of terrane provenance in eastern Ireland (Owen *et al.* 1992).

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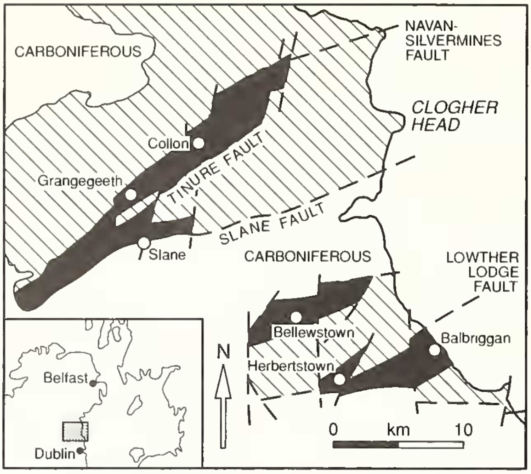
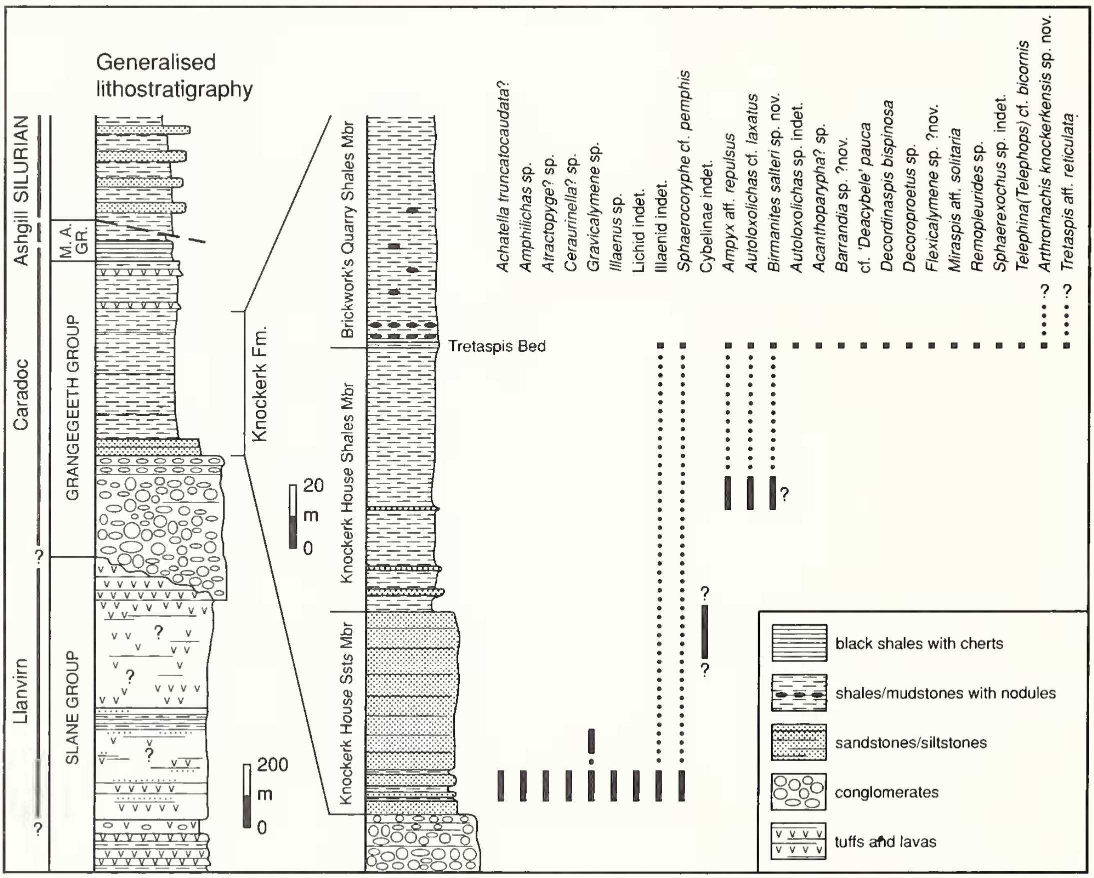


TEXT-FIG. 1. Location map (inset) and summary geological map of Grangegeeth and surrounding area. Ordovician rocks are shaded black; Silurian rocks with oblique lines. (For explanation of fault nomenclature see Owen *et al.* 1992, fig. 1).



TEXT-FIG. 2. Generalised lithostratigraphy of the Grangegeeth area (after Romano 1980) showing ranges of trilobites described in this paper. Question marks in range chart indicate uncertainty of: stratigraphical position (Cybelinae indet.), identification (*Birmanites salteri* sp. nov.), or vertical range (*Arthrorhachis knockerkensis* sp. nov. and *Tretaspis* aff. *reticulata*).

LITHOSTRATIGRAPHY

The Caradoc and Ashgill rocks between Slane, Co. Meath and Collon, Co. Louth in eastern Ireland (Text-fig. 1) were subdivided by Romano (1980) into two groups: the Grangegeeth Group below and Mellifont Abbey Group above. The Grangegeeth Group is up to 1400 m thick and consists of the Collon, Knockerk and Fieldstown Formations. The overlying Mellifont Abbey Group is at least 175 m thick and comprises the Broomfield and Oriel Brook Formations (Text-fig. 2). Rocks of proven or inferred Caradoc age include all the formations of the Grangegeeth Group and the Broomfield Formation of the Mellifont Abbey Group (Brenchley *et al.* 1977). Trilobites have only been recovered from the Knockerk Formation (see below) and Oriel Brook Formation; those from the latter unit require further sampling and will be described in a later publication.

The lithostratigraphy of the Knockerk Formation was described by Romano (1970, 1980). The formation is approximately 400 m thick in the type area around Knockerk House (Romano 1980, p. 64, fig. 6) and is made up of four members (Text-fig. 2). The lowermost member, the Knockerk House Sandstones, consists of massive volcanic sandstones, with tuffaceous shales sporadically present at the base of the unit but more common at the top. The unit is particularly fossiliferous in the basal part with rich brachiopod faunas and rarer trilobites (see Harper 1952 and Romano 1980 for faunal lists and details of localities). The Knockerk House Sandstones grade up into the Knockerk House Shales Member which is only sporadically tuffaceous. Brachiopods are rare in this unit, with trilobites and graptolites dominating. The top of the Knockerk House Shales Member is marked by the distinctive Tretaspis Bed which forms the base of the overlying Brickwork's Quarry Shales Member. The latter shale member is the most richly fossiliferous in the area, particularly near the base where trilobites dominate assemblages which also contain brachiopods, bivalves, gastropods, graptolites, ostracodes, bryozoans, orthocones and echinoderms. The bulk of the material from this unit was collected from the Brickwork's Quarry when it was superbly exposed during its active life but now, due to flooding and disuse, collecting is extremely difficult. Lithologically the member is most variable near the base where tuffaceous silty beds and concretionary horizons are common. The upper part of the member frequently contains layers of concretions and horizons with limonitic spots. It is these two features which serve to distinguish the Brickwork's Quarry Shales from the overlying Mullaghdillon Shales Member, where both concretions and limonitic spots are absent. The junction between these two members is gradational and no faunas have been found in the younger unit. The overlying Fieldstown Formation is not seen in contact with the Mullaghdillon Shales and is distinguished by the presence of thin beds of lithic and pumice tuffs. A single graptolite, *Amplexograptus* sp. indet., has been found in the Fieldstown Formation (Romano 1980).

TRILOBITE DIVERSITY, DISTRIBUTION AND PRESERVATION

The composition and vertical ranges of the trilobite faunas are shown in Text-figure 2. The faunas occur essentially in the lower part of the Knockerk House Sandstones Member and the base of the Brickwork's Quarry Shales Member. Twenty-five trilobite species are recorded from the Caradoc sequences of the Grangegeeth area: eight from the lower part of the Knockerk House Sandstones Member (excluding illaenid indet.) and one from the upper part; eighteen from the base of the Brickwork's Quarry Shales Member, of which three first appear in the middle of the underlying unit. The compositions of the two major faunas are quite distinct and show a marked contrast in diversity. Only one species, *Sphaerocoryphe* cf. *pemphis*, is common to both and the older fauna has fewer skeletal elements (Table 1). Virtually all the specimens are disarticulated; only three occur as complete exoskeletons. Cephala and cranidia dominate (64 per cent – but see caption to Table 1), followed by pygidia (27 per cent), free cheeks (4 per cent), thoracic segments (> 2 per cent) and hypostomata (> 1 per cent). The older fauna shows no particular species dominance from the thirty specimens collected. The younger fauna is dominated by *Tretaspis* aff. *reticulata* (34 per cent of total

TABLE 1. List of trilobite species from the Knockerk Formation, Grangegeeth area, showing the abundance of their skeletal elements. The number of cephala, cranidia and lower lamellae of *Tretaspis* aff. *reticulata* and *Decordinaspis bispinosa* is given as a single entry in each case. Ceph., cephala; Cranid., cranidia; Hypost., hypostomata; Thor. seg., thoracic segments; Pygid., pygidia; Artic. spec., articulated specimens.

	Ceph.	Cranid.	Free cheek	Hypost.	Thor. seg.	Pygid.	Artic. spec.	Total	%
Arthrorhachis knockerkensis sp. nov		9			rare	6		15	4·2
Telephina (*Telephops*) cf. *bicornis* (Ulrich, 1930)		5				1		6	1·7
Remopleurides sp.		3	1					4	1·1
Birmanites salteri sp. nov.	2	3	6	5	4	+50	1	71	20·0
Barrandia sp. ?nov.							1	1	0·3
Illaenus sp.	1		2					3	0·8
illaenid indet.		1	1					2	0·6
Decoroproetus sp.		4	1					5	1·4
Tretaspis aff. *reticulata* Ruedemann, 1901	100				rare	20		121	33·9
Decordinaspis bispinosa Harper and Romano, 1967	10							10	2·8
Ampyx aff. *repulsus* Tripp, 1976		23	2		1	7		33	9·2
Ceraurinella? sp.		3				1		4	1·1
Sphaerocoryphe cf. *pemphis* Lane, 1971	2	26				3		31	8·7
Sphaerexochus sp. indet.		1						1	0·3
Acanthoparyphya? sp.		1						1	0·3
Cybelinae indet. cf. '*Deacybele*' *pauca* Whittington, 1963		6						6	1·7
Cybelinae indet.		1						1	0·3
Atractopyge? sp.	1	3				1	1	6	1·7
Flexicalymene sp. ?nov.		4				2		6	1·7
Gravicalymene sp.		4				4		8	2·2
Achatella truncatocaudata? (Portlock, 1843)	2	1				1		4	1.1
Autoloxolichas cf. *laxatus* (M'Coy, 1846)		2						2	0·6
Autoloxolichas sp. indet.		1						1	0·3
Amphilichas sp.		1			1	1		3	0·8
Lichid indet.		1						1	0·3
Miraspis aff. *solitaria* Reed, 1935		8	1		2			11	3·1
	229 (64%)		14 (4%)	5 (1·4%)	8 (2·2%)	97 (27·2%)	4 (1·1%)	357	100·2

trilobite remains) with *Birmanites salteri* (20 per cent), *Ampyx* aff. *repulsus* (9 per cent) and *Sphaerocoryphe* cf. *pemphis* (8 per cent) constituting the other major elements. All remaining species each make up less than 5 per cent of the sample and six of these comprise less than 1 per cent (Table 1).

This *Tretaspis* dominance with abundant *Ampyx* is similar to that observed by Owen *et al.* (1986) for the fauna from the late Caradoc Raheen Formation of County Waterford. Though there is an absence of asaphids in the Raheen fauna, the nileid *Homalopteon* is the fourth most abundant taxon and may have occupied a similar niche to that of *Birmanites* at Grangegeeth. Owen *et al.* (1986) commented on other faunas dominated by trinucleids and raphiophorids, and concluded that a fairly deep shelf environment was likely for the Raheen fauna. We propose a similar environment for the upper Grangegeeth fauna.

Preservation in both the lower and upper faunas is mainly in the form of moulds. Abrasion is rare although broken sclerites are relatively common. The almost invariably disarticulated exoskeletons indicate reworking, but this is probably largely biogenic rather than current action since there is no size or shape sorting. That some current action has occurred is apparent in the lower faunas where bedding plane assemblages of brachiopods show some degree of orientation (Romano 1980, p. 66).

AGE OF THE TRILOBITE FAUNAS

Knockerk House Sandstones Member

This member contains at least eight species including 'lichid indet.' which is clearly different from the co-occurring *Amphilichas* sp., but excluding 'illaenid indet.' which might belong in *Illaenus* sp. from this member. Six are indeterminate and two have been left in open nomenclature. *Achatella truncatocaudata* is an Ashgill form from the Cautleyan of Pomeroy, Ireland and closely related forms are of Hirnantian age from near Girvan, Scotland (Owen 1986). *Sphaerocoryphe pemphis* occurs in the early Caradoc Balclatchie and Lower Ardwell groups at Girvan. Among the specifically indeterminate forms, *Amphilichas* sp. is morphologically close to Scottish Balclatchie and Lower Ardwell forms while *Atractopyge*? sp. resembles most closely middle Ordovician forms from Estonia. *Ceraurinella*? sp. and *Gravicalymene* sp. are too incomplete to allow comparisons.

Thus, although the fauna shows closest affinities with species of middle Ordovician to Hirnantian age, on balance an early Mohawkian (early Caradoc) age is indicated by the affinities of species to Balclatchie and Lower Ardwell group taxa. No diagnostic graptolites have been recovered from these beds but the accompanying rich brachiopod faunas, showing Scoto-Appalachian affinities, indicate an early Caradoc age (Harper and Parkes 1989; Owen *et al.* 1992).

Brickwork's Quarry Shales Member

Of the eighteen species recognized from this unit, seven are close to previously described species, two are new, two are probably new, five have been identified only to generic level, one is endemic and one is indeterminate. Among the seven forms left in open nomenclature, three are closest to Girvan species (*Sphaerocoryphe pemphis*, *Ampyx repulsus*, *Miraspis solitaria*) of mid Llandeilo to early Caradoc age, two show American affinities of early Caradoc age (*Tretaspis reticulata*) or slightly younger (*Telephina* (*Telephops*) *bicornis*), one is similar to the mid Caradoc Welsh form '*Deacybele*' *pauca*, while *Autoloxolichas* cf. *laxatus* is very close to a form commonly occurring in the Caradoc of Britain, Ireland and Scandinavia. On balance an early Caradoc age is indicated, as was suggested by Brenchley *et al.* (1977) who assigned these shales to the Harnagian mainly on the basis of graptolites indicative of the *Climacograptus peltifer* Biozone (Brenchley *et al.* 1967).

No recent work has been published on the micropalaeontology of this unit but Downie (*in* Brenchley *et al.* 1967) concluded that the chitinozoans clearly pointed to a Caradoc age. Work on the brachiopods (Dr D. A. T. Harper pers. comm.) confirms the correlations suggested by the trilobites.

BIOGEOGRAPHY

Determination of the biogeographical affinities of the Grangegeeth trilobites is crucial to an understanding of the position of the area during the Caradoc relative to the major plates bordering the Iapetus Ocean. As Cocks and Fortey (1990 and references therein) have summarized, the ocean was wide in the early Ordovician and separated the shelf faunas of Laurentia at low latitudes from those of Baltica in mid latitudes and Gondwana further south. The Tornquist Sea also provided a barrier between Baltica and Gondwana. Marginal and deep water facies showed a considerably lower level of endemicity, and pelagic faunas had a climatic (therefore latitudinal) zonation. By the early Caradoc, however, the Tornquist Sea had ceased to prevent transmigration and Iapetus had narrowed sufficiently to allow some mixing of the shelf faunas. However, Avalonia (including the Anglo-Welsh area) had rifted from northern Gondwana with some concomitant divergence in their faunas (see Cocks and Fortey 1990; Fortey and Cocks 1991; cf. Paris and Robardet 1990).

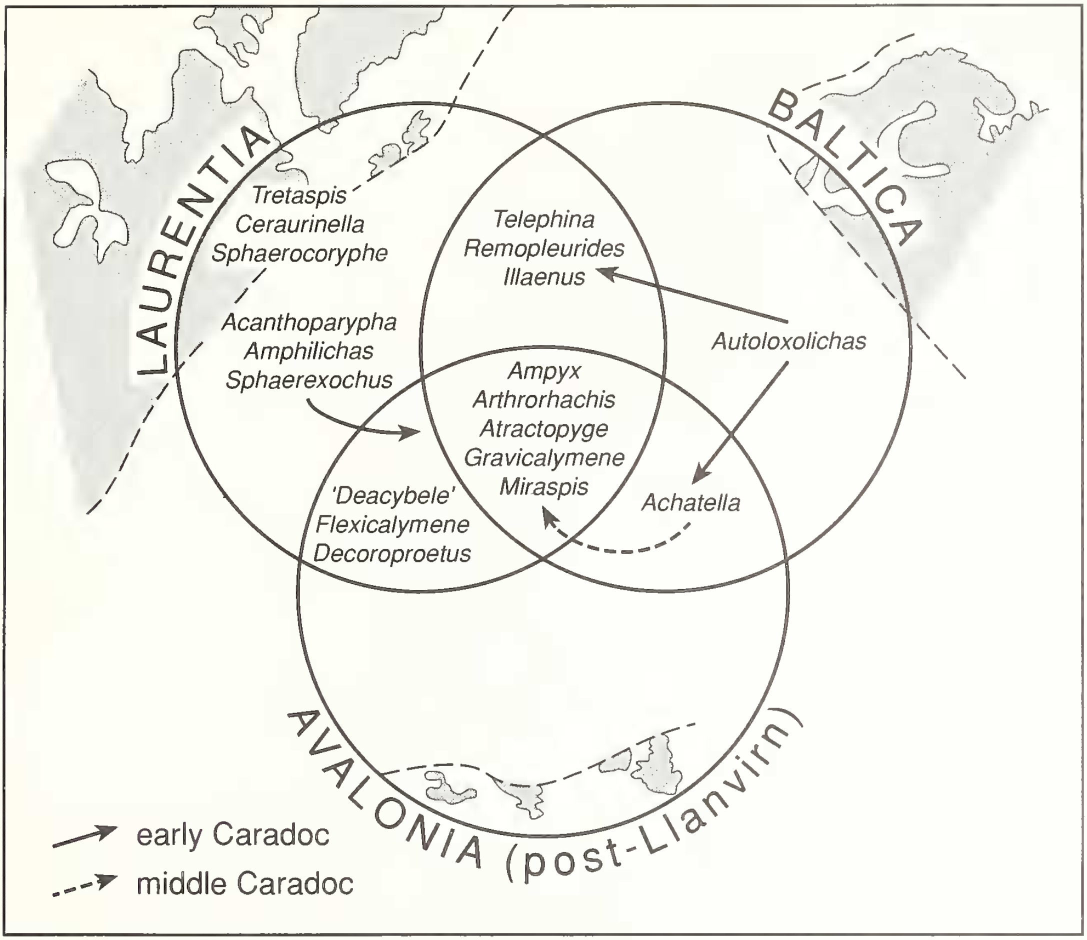
The early Caradoc shelly faunas at Grangegeeth were originally thought to have strong Baltic affinities (Harper 1952; Williams 1956) and plate tectonic models subsequently positioned the Iapetus suture to the north of the area (e.g. McKerrow and Soper 1989). More recent analyses of the Grangegeeth faunas, however (Owen *et al.* 1992 and references therein), point to much stronger links with Laurentian (largely Scoto-Appalachian) faunas during the Caradoc and thus indicate the presence of a more southerly position of the suture with Avalonia.

As the distinction between the faunas of Laurentia (and its outboard terranes) and those of the plates on the other side of Iapetus was breaking down during the early Caradoc, the palaeobiogeographical analysis of early Caradoc faunas (such as those of Grangegeeth) must be based on the critical assessment of the histories of each of the component taxa. It is now clear that only a few taxa are diagnostic in determining the affinities of the Grangegeeth faunas and these would probably be 'swamped' in a statistical analysis by the genera with a much more equivocal palaeogeographical signal.

Only one genus, *Decordinaspis*, is endemic to Grangegeeth. Its ancestry is unclear, but Hughes *et al.* (1975, fig. 120) suggested that it may lie in *Paratrinucleus* from the late Arenig–early Llanivirn (cf. Hughes *et al.* 1975) of New World Island in the oceanic Dunnage Zone of Newfoundland (see Boyce 1987). Text-figure 3 summarizes the earlier distribution of the remaining twenty-one named trilobite genera in the lower Caradoc Grangegeeth faunas. Many have a range which extends into outer shelf and even slope environments and thus it is not surprising that ten had earlier trans-Iapetus occurrences in Baltica and Laurentia (*Illaenus*, *Remopleurides*, *Telephina*), the Anglo-Welsh area and Laurentia (*Decoroproetus*, *Flexicalymene*), or all three areas (*Ampyx*, *Arthrorhachis*, *Atractopyge*, *Gravicalymene*, *Miraspis*). Of all these genera, *Telephina* and possibly *Remopleurides* were pelagic (Fortey 1985), and their earlier restrictions to Baltic and Laurentian sites may be evidence against a high latitude (Gondwanan) location for the Grangegeeth terrane during the Caradoc.

Achatella occurred earlier in Baltica and also in the Irish continuation of the Anglo-Welsh area where it was represented by *A. bailyi* (Salter, 1864) described from the upper Llandeilo to lowest Caradoc Tramore Limestone of Co. Waterford (see Morris 1988). However, it is also known in Laurentian faunas from the early Rocklandian (Sloan 1991, table 2) which is only slightly younger than the Grangegeeth occurrence. It is not therefore diagnostic palaeogeographically. The same applies to the form described here as 'cybeline indet. cf. *Deacybele*'. Although applied to a group of Anglo-Welsh and Baltic species whose first appearance is in the Tramore Limestone, their origin (and possibly generic placement) lies in *Cybeloides*—a Laurentian genus ranging from the early Chazyan (late Llanvirn to early Llandeilo; see Sloan 1991, table 2). *Autoloxolichas* had an earlier history in Baltica but appeared in Laurentia and the Anglo-Welsh area at about the same time as at Grangegeeth.

Birmanites and *Barrandia* are only known from Gondwana (which included the Anglo-Welsh area prior to the Llandeilo). As is noted in the systematic section, the former has a history extending back to the early Ordovician of South East Asia. It has never been recorded from Laurentia but as its earlier occurrences are in deep shelf and upper slope settings, it is not entirely surprising that it might cross the Iapetus divide in the later part of the Ordovician. The same applies to *Barrandia*, hitherto known from the Anglo-Welsh area from the late Arenig to the early to mid Llandeilo. This is also a deep shelf to upper slope trilobite which in the late Arenig of South Wales occurred in the deep water cyclopygid association (Fortey and Owens 1987). A closely allied genus, *Homalopteon*, is known from various deeper water Llandeilo (and possibly Llanvirn) to Caradoc faunas in the



TEXT-FIG. 3. Venn diagram showing the occurrences of selected trilobite genera from the Knockerk Formation during the Caradoc, with reference to Laurentia, Baltica and Avalonia. The arrows show the 'direction' and timing of migratory pathways. The relative positions of the three continental plates are not intended to be accurate.

Anglo-Welsh area. There is a single record of this genus in a similar bathymetric setting in the Llandeilo at Girvan (Ingham and Tripp 1991, p. 27), further testimony to the unreliability of such taxa for biogeographical reconstructions.

Six genera had an earlier history confined to Laurentian and Scoto-Appalachian faunas (Text-fig. 3), but of these, *Acanthopărypha*, *Amphilichas* and *Sphaerexochus* appeared in the Anglo-Welsh area during the early Caradoc, contemporaneous with or only slightly after the Grangegeeth faunas (Owen *et al.* 1992, fig. 2). The remaining three, *Sphaerocoryphe*, *Tretaspis* and *Ceraurinella* did not extend their ranges into the Anglo-Welsh or Baltic areas until the mid Caradoc, late Caradoc and mid Ashgill, respectively. All have environmental ranges from pure limestone facies to outer shelf muds but they are the most reliable indicators of the provincial affinities of the Grangegeeth trilobite genera.

The Laurentian/Scoto-Appalachian affinities of the Grangegeeth Caradoc faunas are even more striking at species level. The species of *Amphilichas*, *Ampyx*, *Flexicalymene*, *Miraspis*, *Sphaerocoryphe*, *Telephina* and *Tretaspis* are all closest to older or coeval Laurentian/Scoto-Appalachian taxa and that of *Achatella* closest to a younger species from such faunas. In contrast, only the species of *Autoloxolichas* and 'cybeline indet. cf. *Deacybele*' have their strongest affinity to (younger) Baltic and Anglo-Welsh forms.

The biogeographical affinity to Laurentian/Scoto-Appalachian faunas is evident at all the fossiliferous levels of the Knockerk Formation (Text-fig. 2) and is also seen in the associated brachiopods. The Grangegeeth area probably represents a discrete terrane within the Iapetus Suture zone in eastern Ireland (Harper and Parkes 1989) but was closer to Laurentia than Baltica or Gondwana during the early Caradoc. Limited graptolite evidence, however, suggests a position closer to Gondwana during the Llanvirn and hence a northward migration of the Grangegeeth terrane during the mid Ordovician (Owen *et al.* 1992).

LOCALITIES

Most of the trilobite faunas described were collected from the localities listed below within the Grangegeeth area. To avoid repetition under the section heading 'Horizon and locality', details of each locality and stratigraphical information are listed here. All material was collected from the Knockerk Formation, only the member is listed below.

Locality 1: (Hull *et al.* 1871; Harper 1952, p. 88; Romano 1980, p. 66); small quarry to east of road, 436 m north of Grangegeeth crossroads; base of Knockerk House Sandstones Member.

Locality 3: (Harper 1952, p. 87; Romano 1980, p. 66); small quarry to west of road, 419 m 348° from Grangegeeth crossroads; base of Knockerk House Sandstones Member.

Collon Quarry: (Romano 1980, p. 67); southern end of large quarry, 554 m 175° from Collon crossroads; base of Knockerk House Sandstones Member.

Locality 210A: (Romano 1970); ditch section, 3226 m 330° from Slane crossroads; lower part of Knockerk House Shales Member.

Locality 210B: (Romano 1970); ditch section, 2969 m 332° from Slane crossroads; approximately middle of Knockerk House Sandstones Member.

Locality 38: (Harper 1952, p. 89; Romano 1980, p. 67); roadside exposure, 654 m 210° from Collon crossroads; ?upper part of Knockerk House Sandstones Member/lower Knockerk House Shales Member.

Locality 190: (Brenchley *et al.* 1967, p. 298); temporary well digging to west of road, 1007 m south of Grangegeeth crossroads; exact horizon not known, but possibly near base of Brickwork's Quarry Shales Member.

Locality 208 and Locality 209: (Romano 1980, p. 65); temporary exposures, 2952 m 340° and 2902 m 337° from Slane crossroads respectively; middle to upper part of Knockerk House Shales.

Locality 26: (Harper 1952, p. 89; Romano 1980, p. 70); ditch section and adjacent small quarry, 2214 m 102° from Grangegeeth crossroads; ?Knockerk House Shales Member to basal Brickwork's Quarry Shales Member.

Brickwork's Quarry: (Romano 1980, Fig. 6, p. 68); large quarry (flooded and partly overgrown in 1991), 2800 m 340° from Slane crossroads; from Tretaspis Bed through basal part of Brickwork's Quarry Shales Member.

Repositories

All figured specimens are housed in the National Museum of Ireland (NMI), Geological Survey of Ireland (GSI) or Liverpool Museum (LM); other material is deposited in the above Institutions and the Natural History Museum, London (BM It). Some incomplete or poorly preserved specimens are in the collections of the Department of Earth Sciences, University of Sheffield.

SYSTEMATIC PALAEONTOLOGY

Family METAGNOSTIDAE Jaekel, 1909
Genus ARTHRORHACHIS Hawle and Corda, 1847

Type species. Arthrorhachis tarda Hawle and Corda, 1847; from the Králův Dvůr Formation of Ashgill age, near Beroun, Czech Republic.

Arthrorhachis knockerkensis sp. nov.

Plate 1, figs 1–7

?1871 *Agnostus trinodus*; Hull *et al*., p. 29.
1952 '*Agnostus*' *girvanensis* Reed; Harper, p. 89.
?1952 *Agnostus trinodus*; Harper, p. 90.
1967 *Trinodus* sp.; Brenchley *et al*., pp. 298, 301, pl. 7.
1980 *Trinodus* sp.; Romano, pp. 68, 70, ?71.

Derivation of name. After the townland of Knockerk in which Brickwork's Quarry is situated.

Material. Holotype: NMI F20974. Paratypes: NMI F20971–3, F20975A–B; LM 1988.216.463; BM It.25694–It.25695*a–b*.

Horizon and locality. NMI F20971–F29075 and BM It.25694 from concretions approximately 1 m above the Tretaspis Bed; BM It.25695*a–b* from the Tretaspis Bed, Brickwork's Quarry; L.M. 1988.216.463 from Loc. 26.

Diagnosis. Glabella with constriction; well-marked posterolateral cephalic spines. Subquadrate outline to pygidium, small triangular pygidial axis and very slightly divergent pygidial spines.

Description. Cephalic outline almost square, approximately as long as greatest width, latter being just anterior to mid-length. Glabella occupies 55–65 per cent of cephalic length, narrowing forwards slightly in front of basal lobes, smoothly rounded to blunt-ended anteriorly and constricted at about mid-length. Glabella strongly convex transversely, gently convex longitudinally. Triangular basal lobes about twice as wide as long (exs.), not meeting mesially thus the mesial glabella between them is bluntly pointed; delimited by furrows which are broader abaxially. Axial furrows broad; fairly well incised laterally, less so in front of glabella. Cheeks of fairly constant width, steeply declined laterally, gently declined anteriorly. Border widest anterolaterally; narrowing markedly near genal angles where there is a small (coaptative) notch in the margin. Short, rearwardly directed spines at posterolateral corners of cephalon. No sculpture except faint median glabellar node situated at constriction on internal mould of some specimens (possibly elongated longitudinally on one specimen).

Pygidium sub-quadrate in outline, slightly wider than long; maximum transverse width towards rear end. Axis occupies 50 per cent or less of pygidial length, sub-triangular in outline, narrowing evenly rearwards at 55–70° to rounded posterior margin; delimited by well-incised furrows. Short articulating half-ring separated from anterior ring by deep furrow. Anterior ring only slightly shorter (sag.) than second ring and about two-thirds as long as terminal piece. Posterior ring furrow complete, anterior furrow interrupted by longitudinal, gently convex (tr.) ridge which crosses anterior and second axial rings and develops as a tubercle on the latter. Axis strongly convex (sag. and tr.). Pleural field steeply declined laterally, less so posteriorly. Border generally flat; widest posterolaterally where extended into pair of short, slightly divergent spines which do not extend beyond level of posterior margin of pygidium. No sculpture observed.

Discussion. Although there is clear intraspecific variation, the well-developed cephalic and pygidial spines, small triangular pygidial axis and nearly parallel-sided pygidium are features not collectively seen in any other species of this genus. Thus *A. knockerkensis* has longer, more posteriorly placed pygidial spines, a more parallel-sided pygidium with a slightly narrower axis than *A. tarda* from the Ashgill of Bohemia, Scandinavia, the British Isles and Kazakhstan (Whittington 1950; Kielan 1960; Pek 1977; Owen 1981; Ahlberg 1989). It has a more quadrate outline to the pygidium and narrower axis than *A. doulargensis* Tripp, 1965, from the Llandeilo of Girvan, Scotland, and the closely related *A. elspethi* Hunt, 1967, from the Llandeilo-lower Caradoc of the southern Appalachians and Sweden (see Ahlberg 1988). *A. knockerkensis* has a less well-rounded cephalon and shorter pygidial axis than *A. aspinosus* Tripp, 1976, and a more constricted glabella and shorter pygidial axis than *A. comes* Tripp, 1976, both from the Llandeilo Superstes Mudstone at Girvan. *A. girvanensis* Reed, 1903, from the Balclatchie and Lower Ardwell groups is distinct in its shorter glabella and broader, less tapered pygidial axis. *T. agnostiformis* M'Coy, from the Caradoc of

Enniscorthy, Co. Wexford, is the only species now ascribed to *Trinodus* (see Fortey 1980, p. 26) and because of its poor preservation cannot be closely compared to the Grangegeeth species. The position of the median glabellar node opposite the glabellar constriction precludes the assignment of the Grangegeeth species to *Galbagnostus* Whittington, 1965*b*, where this node is much more forwardly placed.

Family TELEPHINIDAE Marek, 1952
Genus TELEPHINA Marek, 1952

Type species. Telephus fractus Barrande, 1852, by original designation; from the Nučice Beds and Králův Dvůr Shales (late Caradoc to early Ashgill) of Bohemia.

Subgenus TELEPHINA (TELEPHOPS) Nikolaisen, 1963

Type species. Telephus granulatus Angelin, 1854, by original designation; from the Elnes Formation ('*Ogygiocaris* Shale') (Llanvirn) of Hadeland, Norway.

Telephina (*Telephops*) cf. *bicornis* (Ulrich, 1930)

Plate 1, figs 8–11, 14

1967 *Telephina* (*Telephops*) sp. cf. *T.* (*T.*) *bos* Nikolaisen; Brenchley *et al.*, pp. 298, 302, pl. 7, figs 7–8.
1980 *Telephina* (*Telephops*) cf. *bicornis* (Ulrich); Romano, p. 69.
1988 *Telephina* (*Telephops*) cf. *bos* Nikolaisen, 1963; Morris, p. 227.

Material. NMI F20976–F20979; NMI G.108/1965 (figured by Brenchley *et al.*, 1967, pl. 7, figs 7–8).

Horizon and locality. All from concretions approximately 1 m above Tretaspis Bed, except NMI F20979 from Tretaspis Bed, Brickwork's Quarry and possibly from Loc. 26.

Discussion. The Irish specimens closely resemble those assigned to the American species *T.* (*T.*) *bicornis* (Ulrich, 1930, pl. 4, figs 1–14) from the Whitesburg Limestone (late Whiterockian) of

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EXPLANATION OF PLATE 1

Figs 1–7. *Arthrorhachis knockerkensis* sp. nov. 1, NMI F20971; internal mould of cephalon, dorsal view, ×7. 2, NMI F20972; internal mould of cephalon, dorsal view, ×11. 3, 6, NMI F20973; internal mould of cephalon, dorsal and lateral views, ×7, ×10, respectively. 4, NMI F20974 (holotype); internal mould of pygidium, dorsal view, ×9. 5, 7, NMI F20975; internal mould of pygidium, dorsal and lateral views, both ×11. All from concretions approximately 1 m above Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry.

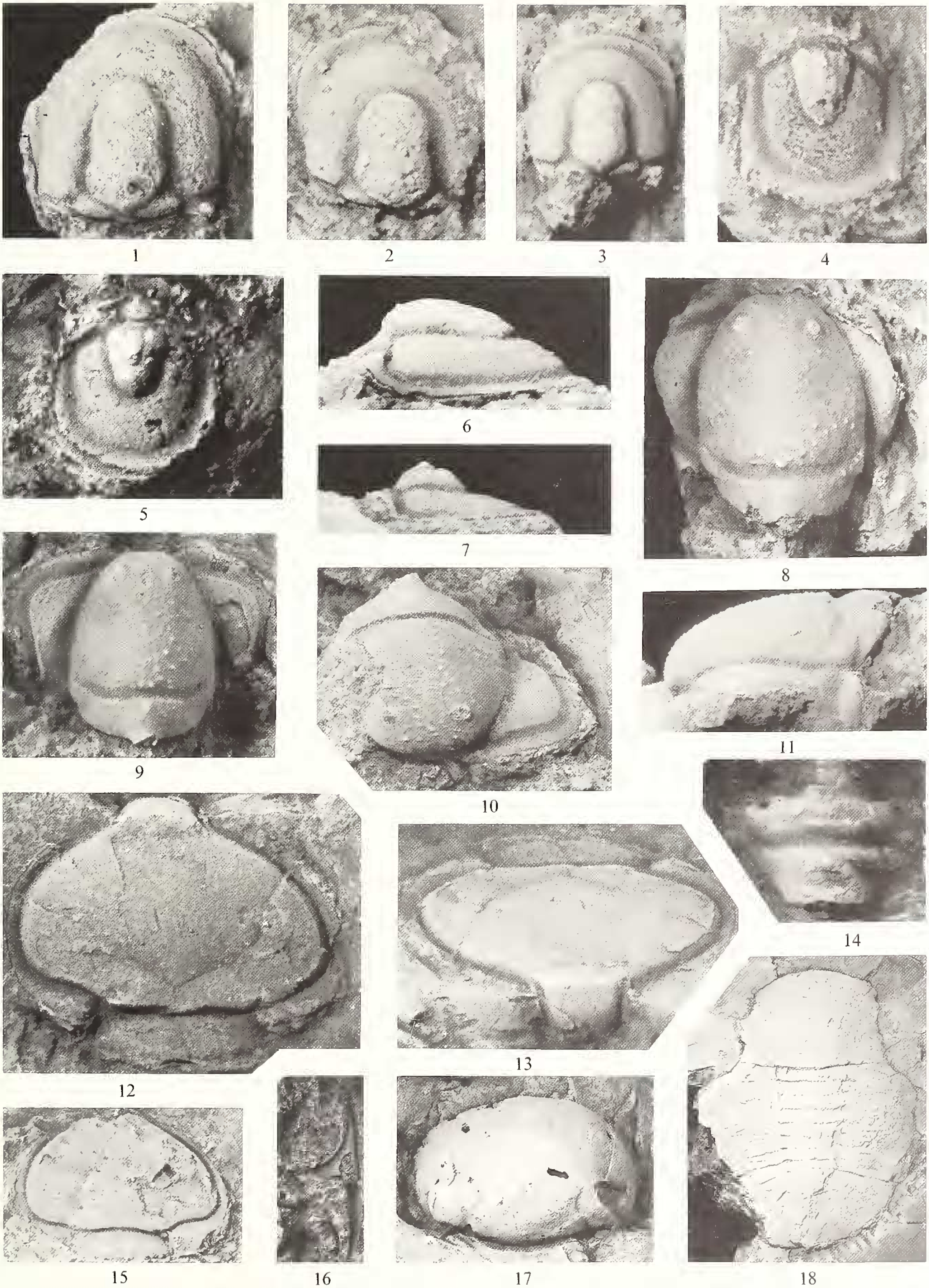
Figs 8–11, 14. *Telephina* (*Telephops*) cf. *bicornis* (Ulrich, 1930). 8, 11, NMI F20976; internal mould of cranidium, dorsal and lateral views, both ×4. 9, NMI F20977; internal mould of cranidium, dorsal view, ×4. 10, NMI F20978; internal mould of cranidium, frontal view, ×4. 14, NMI F20979; internal mould of pygidium, dorsal view, ×7. All except 14 from concretions approximately 1 m above Tretaspis Bed (14 from Tretaspis Bed), Brickwork's Quarry Shales Member; Brickwork's Quarry.

Figs 12–13, 15–16. *Remopleurides* sp. 12–13, NMI F20980; internal mould of cranidium, dorsal and frontal views, both ×6. 15, NMI F20981; internal mould of cranidium, dorsal view, ×3. 16, NMI F20982; internal mould of free cheek, ×4. All except 16 from Tretaspis Bed (16 from concretions approximately 1 m above Tretaspis Bed), Brickwork's Quarry Shales Member; Brickwork's Quarry.

Fig. 17. *Illaenus* sp. NMI F14032/A (figured by Harper 1952, pl. 5, fig. 6 as NMI 1951/17); internal mould of cephalon, dorsal view, ×1·5. Base of Knockerk House Sandstones Member; Loc. 1.

Fig. 18. *Barrandia* sp. ?nov. NMI F20983; internal mould of nearly complete specimen, dorsal view, ×1·5. Probably from near base of Brickwork's Quarry Shales; Brickwork's Quarry.

PLATE 1



ROMANO and OWEN, *Irish Caradoc trilobites*

Virginia. Minor differences are the generally finer ornament on the Irish specimens, particularly on the occipital ring, and the possibly smaller glabellar spines (although only one spine has so far been seen on the Grangegeeth specimens). Also the American species does not appear to show the shallow lateral occipital furrow. The pygidium described above differs from that of *T.* (*T.*) *bicornis* in apparently lacking the fine tuberculation on the axial rings (however, the Irish specimen is an incomplete, deformed internal mould). Ulrich compared his new species with *T.* (*T.*) *granulata* Angelin and figured copies of Swedish specimens from the *Ogygiocaris* shale. The proportions of the cranidium (in Ulrich 1930, pl. 1, fig. 19) are quite unlike those of the present material although another specimen (pl. 1, fig. 22) is more similar to the Irish cranidia. The pygidium of *T.* (*T.*) *granulata* however shows only single tubercles on the axial segments. This latter character was also noted by Nikolaisen (1963) who figured two Norwegian cranidia of this species, the glabella of which is relatively longer and more coarsely ornamented than in the Irish specimens.

Originally the single cranidium known from Grangegeeth was compared to *T.* (*T.*) *bos* Nikolaisen (Brenchley *et al.* 1967), but additional and better preserved material from Grangegeeth differs from the Norwegian species in having a relatively narrower cranidium and paired spines, as opposed to single tubercles, on the pygidial axial rings.

Family REMOPLEURIDIDAE Hawle and Corda, 1847
Genus REMOPLEURIDES Portlock, 1843

Type species. *Remopleurides colbii* Portlock, 1843, by subsequent designation of Miller (1889); from the Killey Bridge Beds, (Cautleyan), Desertcreat, Co. Tyrone, Northern Ireland.

Remopleurides sp.

Plate 1, figs 12–13, 15–16

?1871 *Remopleurides* sp.; Hull *et al.*, p. 29.
?1952 *Remopleurides* sp.; Harper, p. 90.
1967 *Remopleurides* sp. indet.; Brenchley *et al.*, p. 298.
1980 ?*Remopleurides* sp.; Romano, p. 68.
1980 *Telephina* (*Telephina*) sp.; Romano, p. 68.

Material. NMI F20980, NMI F20981*a–b*, NMI F20982.

Horizon and locality. From Tretaspis Bed, Brickwork's Quarry, except NMI F20982 from concretion approximately 1 m above Tretaspis Bed in same quarry.

Discussion. In general glabellar outline and width of the tongue, *Remopleurides* sp. is very close to *Sculptella scripta* Nikolaisen, 1983, pl. 9, figs 9–11, and *S. scriptoides* Nikolaisen, 1983, pl. 10, figs. 1–8 from the Llandeilo of the Oslo Region. As no sculptural lines are evident in the internal or external moulds of the Irish species, it is therefore provisionally placed in *Remopleurides*. The relatively wide glabella, short tongue and rapidly widening palpebral rims posteriorly are, however, not features collectively seen in any other remopleuridid species. Among the described Scottish species of *Remopleurides*, the Irish form is closest to *Remopleurides* sp. from the Upper Balclatchie Group (Tripp 1980, pl. 1, fig. 16), although the glabellar tongue is considerably narrower in the Irish specimen. *R.* cf. *granensis* Størmer (Owen 1981, pl. 1, figs 19–23) from the Ashgill of the Oslo region has a glabellar tongue which is closer to that of *Remopleurides* sp., but the latter does not show the granulation or occipital tubercle of the Norwegian species. Middle Ordovician remopleuridids from Norway include *Remopleurides* sp. G from the late Caradoc Solvang Formation in Ringerike (Nikolaisen 1983, pl. 6, figs 9–11), which has a relatively narrow glabellar tongue but shows strong sculpture on the occipital ring. Until more and better preserved material is available it is preferred to leave the present species in open nomenclature.

Family ASAPHIDAE Burmeister, 1843
Subfamily ASAPHINAE Burmeister, 1843
Genus BIRMANITES Sheng, 1934

Type species. Ogygites birmanicus Reed, 1915; from the Hwe Mawng Beds (lower Ordovician) of Hwe Mawng and Hpakhi, northern Shan States, Burma.

Discussion. The status of *Birmanites* Sheng, 1934 has been discussed by Chugaeva (1958), Zhou *et al.* (1984), Zhou and Dean (1986), and Tripp *et al.* (1989). Zhou *et al.* pointed out that a number of species currently referred to *Ogygites* Tromelin and Lebesconte, 1876, *Pseudobasilicus* Reed, 1931, *Birmanites*, *Opsimasaphus* Kielan, 1960 and *Nobiliasaphus* Přibyl and Vaněk, 1965, may be assigned to *Ogygites*, based on the diagnosis given by Chugaeva (1958) and freely translated with minor additions by Zhou *et al.* (1984, p. 17). Chugaeva considered *Birmanites* and *Pseudobasilicus* as junior synonyms of *Ogygites* but Zhou *et al.* regarded *Ogygites* as being insecurely founded and, pending an ICZN decision (Henningsmoen *et al.* 1980) preferred to use *Birmanites*. We follow Zhou *et al.* in using *Birmanites* in preference to *Ogygites* (cf. Chugaeva 1958), and agree with Zhou and Dean (1986, p. 754) in considering *Opsimasaphus* a junior subjective synonym of *Birmanites*.

Birmanites salteri sp. nov.

Plate 2, figs 1–10

1866 *Asaphus radiatus*; Salter, pl. 18, figs 4–5.
1952 *Pseudobasilicus* sp.; Harper, pp. 90, 108, pl. 5, fig. 2.
1966 *Opsimasaphus* sp.; Whittington, p. 78.
1967 *Pseudobasilicus* sp. indet.; Brenchley *et al.* p. 298.
1980 ?*Opsimasaphus* sp. indet.; Romano, p. 67.
1980 *Opsimasaphus* sp.; Romano, pp. 68–70.
1988 *Opsimasaphus radiatus* (Salter); Morris, p. 253.

Derivation of name. After J. W. Salter who first figured a specimen of the species now described.

Material. Holotype: NMI F20984. Paratypes NMI F20985–F20991; BM It.25696–It.25703; Geological Survey Museum (GSM) 12386, and counterparts 12387 and 12840 (the latter figured by Salter 1866, pl. 18, fig. 4 and Harper 1952, pl. 5, fig. 2).

Horizon and locality. Most material is from the Tretaspis Bed and overlying concretions, Brickwork's Quarry. The remainder from Locs 190, 209, 210A and from the ditch section at Loc. 26. GSM material is probably from locality 8 of the Irish Survey Memoir (Hull *et al.*, 1871, see Harper 1952, p. 108).

Diagnosis. Asaphinid with preglabellar field approximately 40 per cent of total cranidial length and equal in width to almost 140 per cent of the width of the cranidium across the palpebral lobes. Well marked posterior median glabellar lobe with small tubercle. Front of eye lobes one-third cranidial length from posterior margin. Anterior margin of frontal glabellar lobe with blunt point; weakly incised preglabellar furrow. Pygidial axis with up to 14 straight axial rings, pleural fields with 7 or 8 ribs.

Description. Cranidium nearly as wide as long, widest part (excluding posterior borders) at about two-thirds distance from posterior margin. Glabella occupies just over 60 per cent of cranidial length. Occipital ring about one-seventh glabellar length, transversely gently convex and more or less flat sagittally. Glabella (excluding occipital ring) three-quarters as wide as long, gently convex (trs.); longitudinal profile fairly flat but sloping down gently to anterior margin. Anteriorly glabella evenly rounded, frontal margin delimited by change in slope rather than preglabellar furrow. Axial furrows absent opposite eye lobes where lateral margin of glabella indistinct, elevated above the level of the weakly incised anterior and posterior portions of the axial furrows. Wide, shallow basal glabellar furrows extend in slight curve from occipital furrow towards anterior end of palpebral lobes but die out before reaching axial furrows. Longitudinal ridge-like median glabellar lobe between glabellar furrows increases slightly in height posteriorly and abruptly ends before occipital furrow where it carries a small median tubercle. Palpebral lobes long (exs.), equal to 20 per cent of maximum cranidial length; anterior of lobe at 35 per cent of cranidial length from posterior end. Palpebral lobes semi-circular in outline, flat, relatively narrow and separated from fixed cheeks by very shallow palpebral furrow. Top of palpebral lobe lies just below level of highest part of glabella. Anterior facial sutures curve strongly outwards and forwards to maximum cranidial width, then curve evenly forwards to meet in dorsally situated blunt point. Preglabellar field long (40 per cent of total cranidial length) and wide (140 per cent the cranidial width at the palpebral lobes), sloping very gently forwards in front of glabella then flattening to anterior margin. Lateral portions of fixed cheeks slope gently abaxially. Posterior branches of facial sutures imperfectly preserved. Posterior borders appear to be slightly shorter (exs.) than occipital ring; posterior border furrows deepen abaxially. Free cheeks poorly preserved but wide (trs.) level with palpebral lobes. Long, wide genal spines with broad base and possibly incurved posteriorly. Cheeks with doublure of unknown width. Sculpture on cephalon (present on internal and external surfaces unless stated) consists of: (a) fine ridges on anterior half of glabella directed subparallel to margins. (b) slightly coarser ridges on posterior half of glabella, concentrically arranged around median tubercle. (c) ridges on preglabellar field and fixed cheeks running subparallel to each other and cranidial margins. (d) ridges on palpebral lobes where subparallel to posterior margins and oblique to anterior margins of lobes. (e) symmetrical, concentrically arranged ridges, anteriorly convex, on occipital ring. (f) faint longitudinal (exs.) ridges on posterior border (not known if present on internal mould). (g) ridges on free cheeks running subparallel to margins.

Excluding wings, hypostoma estimated to be approximately 75 per cent as wide as long; widest just posterior to midlength. Lateral margins quite strongly curved, posterior margin deeply notched with posteriorly directed prongs at least 25 per cent as long as hypostoma mesially. Suboval convex body slightly wider than long with delimiting furrow more pronounced posterolaterally. Pair of prominent maculae situated posterolaterally of convex body, area between maculae at higher level than lateral borders. Anterior wings separated from oval body by inwardly curved border. Lateral borders covered with fine raised lines subparallel to margins.

Complete thorax unknown. Axis about 25 per cent of thoracic width and gently convex (trs.), axial furrows shallow. Pleurae of uniform width (exs.), gently curved rearwards from about mid-length (trs.) and extending into short posterolaterally directed, bluntly rounded spines. Oblique pleural furrows crossing from anterior end adaxially to near posterior margin at distance of about 75 per cent pleural length (trs.) from axis. Abaxial half of ventral surface of pleurae covered with fine longitudinal (exs.) ridges.

Pygidium approximately semi-circular in outline with gently curved anterior margin; length to width ratio lies between 1:1·4 and 1:2·0 ($N = 23$). Gently tapering axis very narrow (varying from 10–20 per cent of pygidial width anteriorly), and between 70–?90 per cent of pygidial length. Axial furrows straight and faint, converging evenly posteriorly at about 20°. Axis stands slightly above flat pleural regions. In lateral view axis highest anteriorly and posteriorly. Seven (or 8) to 14 axial rings and rounded terminal piece, separated by straight axial ring furrows; posterior axial rings being shorter (sag.). Seven (occasionally 8) pleural ribs present, curved gently rearwards with abaxial end slightly wider (exs.) and terminating before margin. Posterior pleurae curve rearwards more strongly. Interpleural furrows distinct, rarely faint pleural furrows present on anterior pleurae. Doublure wide, occupying just over half width of pleural field, except posteriorly where constricted behind axis. Doublure covered with up to twenty subparallel terrace lines lying oblique to pygidial margin. Between these

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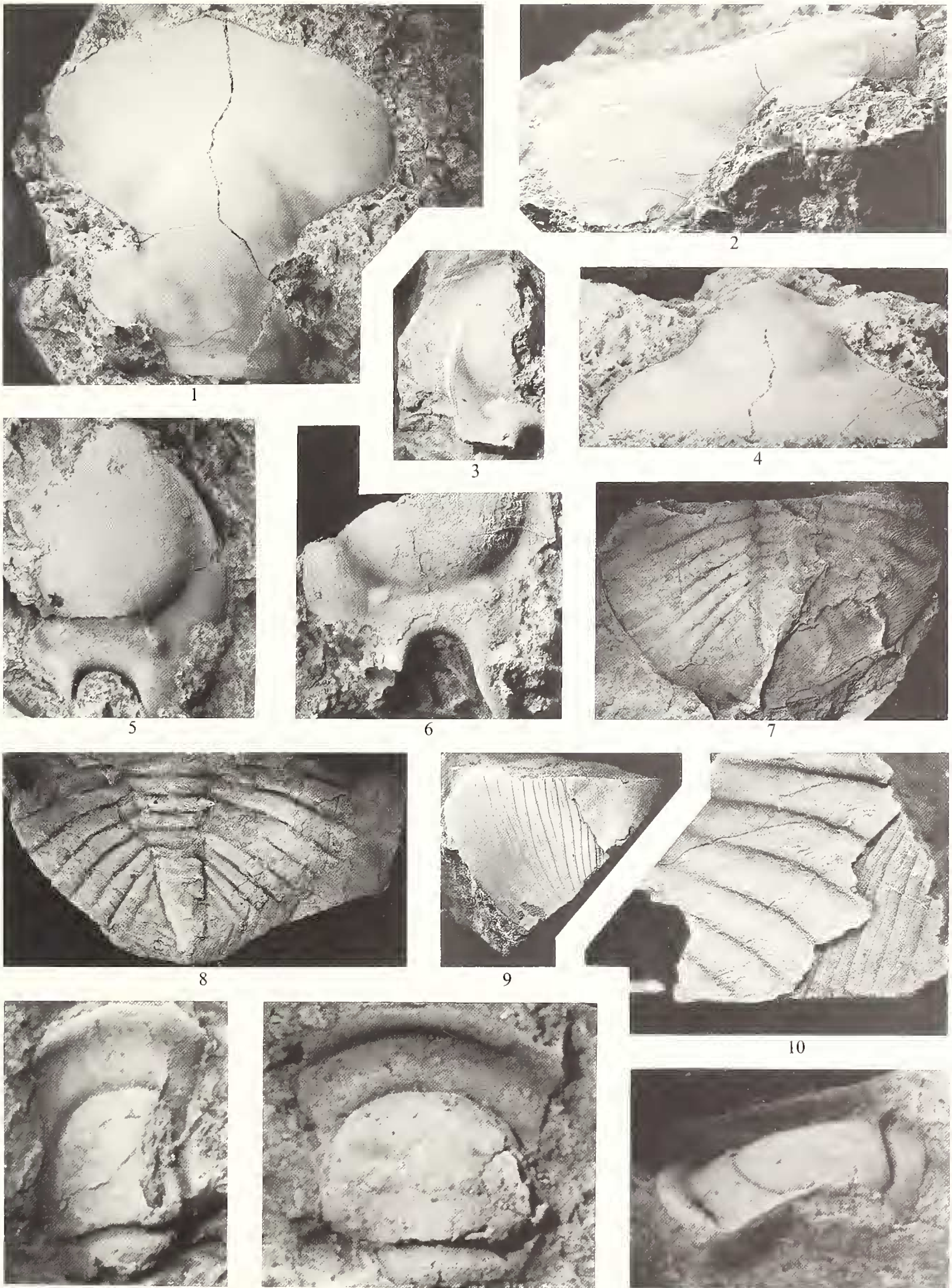
EXPLANATION OF PLATE 2

Figs 1–10. *Birmanites salteri* sp. nov. 1–2, 4, NMI F20984 (holotype); internal mould of cranidium, dorsal, lateral and frontal views respectively, all ×2. 3, NMI F20985; internal mould of hypostoma, ventral view, ×2. 5, NMI F20986; internal mould of hypostoma, ventral view, ×4. 6, NMI F20987; cast of external mould of hypostoma, ventral view, ×3. 7, NMI F20988; internal mould of pygidium, dorsal view, ×1. 8, NMI F20989; internal mould of pygidium, dorsal view, ×1. 9, 10, NMI F20990, 91; internal moulds of pygidia showing doublure and terrace lines, dorsal views, ×1·5, ×3, respectively. 1–6, 9–10 from concretions approximately 1 m above Tretaspis Bed, 7–8 from Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry.

Figs 11–13. *Decoroproetus* sp. 11, NMI F14026 (figured by Harper 1952, pl. 5, fig. 3 as NMI 1951/12); internal mould of cranidium, dorsal view. 12, LM 1988.216.445; cast of external mould of cranidium, dorsal view. 13, LM 1988.216.444, cast of external mould of cranidium, lateral view. All from ?Knockerk House Shales Member to basal Brickwork's Quarry Shales Member; Loc. 26. All ×11.



ROMANO and OWEN, *Irish Caradoc trilobites*

main terrace lines are finer striations aligned at angle to former. Postaxially and along downturned border the terrace lines lie closer together.

The relative abundance of pygidia has allowed some quantitative analysis. Length (sag.) and width (trs.) measurements on complete shields and axes indicate generally good linear relationships. All tend to show isometric growth, at least in forms larger than 25 mm wide, and there is no indication of dimorphism or clustering into instars.

Discussion. Birmanites salteri is fairly close to *B. hupeiensis* Yi, 1957, from the upper Llanvirn to lower Llandeilo Miaopo Formation of Yichang, Hubei Province and the broadly contemporaneous Shihtzupu Formation at Zunyi, Guizhou Province from where Yi's species was described by Zhou *et al.* (1984, p. 17, fig. 3*c–f*, *i–j*, *m*). Zhou *et al.* noted that *B. hupeiensis* and the type species are the only ones in which the width of the preglabellar area exceeds the palpebral width by 50 per cent (a figure approached by *B. salteri*). However, in both of the Asian species the length of the preglabellar field is approximately equal to that of the glabella (data for *B. birmanicus* taken from Moore 1959, p. O359, fig. 268.7), and the type species has well-marked cephalic sculpture and only 7 or 8 axial rings on the pygidium. *B. hupeiensis* lacks cephalic sculpture but does not show the slightly pointed mesial part of the anterior edge of the cranidium seen in *B. salteri*. The hypostoma of the Irish species is broadly similar to that of *B. hupeiensis*, but is relatively longer and the inner edges of the posterior fork are considerably less divergent. The pygidia of the Irish species differ from those of *B. hupeiensis* in the slightly higher number of axial rings (maximum 14 as opposed to maximum 12) and pleural ribs (7 or 8 rather than 6), and the generally longer axis (70–?90 per cent rather than 55–70 per cent).

Birmanites sp. from the Shihtzupu Formation (Zhou *et al.* 1984, p. 18, fig. 4*a–c*, *g*) has the pygidial axis of comparable length to that of *B. salteri* but its cranidium has a much shorter and narrower preglabellar area. The hypostoma of *B. salteri* is proportionately longer, and the hypostomal forks less divergent, than that of *B.* sp.

Birmanites aff. *asiaticus* (Petrunina *in* Repina *et al.* 1975) described by Zhou and Dean (1986, p. 754, pl. 59, figs 7, 10–11, 13–15) from the Caradoc of Chedao, Gansu Province, China has a short preglabellar area (approximately 30 per cent of the glabellar length) and, as noted by Zhou and Dean, this is comparable to the condition seen in *B. asiaticus* from the Ashgill of southern Tian-Shan and *B. latus* (Angelin, 1851; Kielan 1960) from the Ashgill of Västergötland, Sweden.

Birmanites sp. of Tripp *et al.* (1989, p. 36, fig. 5*d–e*, *i*, *l*) from the Tangtou Formation (probably lower Ashgill) of Jiangsu, China has a long preglabellar area but proportions are difficult to assess from the illustrated specimen. The pygidia from the Tangtou Formation have the axis occupying 65 per cent of the sagittal length, 9 axial rings and 9 pleurae. Tripp *et al.* considered *B.* sp. to be very close to *B. juxianensis* Ju, from the Huangnehkan Formation of Quxian, Zhejiang, differing only in the latter's much narrower pygidial border.

Family NILEIDAE Angelin, 1854
Genus BARRANDIA M'Coy, 1849

Type species. Barrandia cordai M'Coy, 1849, by monotypy; probably from the *Glyptograptus teretiusculus* Shales of early Llandeilo age (Hughes 1979), Powys, Wales.

Barrandia sp. ?nov.

Plate 1, fig. 18

1980 *Barrandia* sp.; Romano, p. 68.

Material. NMI F20983.

Horizon and locality. Not found *in situ*, probably from about 0·35–0·40 m above the Tretaspis Bed, Brickwork's Quarry.

Description. Specimen oval in outline, maximum width (excluding free cheeks) equal to approximately 75 per cent of the length. Cranidium nearly flat but steeply downturned anteriorly. Very faint axial furrows which diverge anteriorly in gentle arc, possibly just reaching anterior margin. Glabellar lobes and furrows absent. Glabella longer than wide. Facial sutures very poorly preserved but fixed cheek about one-quarter cranidial width. Though ill-defined, anterior part of 'palpebral' area approximately level with midlength of glabella. Occipital ring, posterior border absent, free cheeks and hypostoma unknown.

Thorax just over twice as long as wide with axis occupying about 35 per cent of thoracic width anteriorly. Axis narrows gradually posteriorly to just under 75 per cent its anterior width. Axial furrows not well-defined. Eight thoracic segments; pleurae parallel-sided and each bears a pleural furrow which runs obliquely from the anteromesial corner terminating about 75 per cent of the distance (trs.) along pleura. Distal ends of pleurae curved slightly rearwards.

Pygidium nearly flat; just over twice as wide as long, semicircular in outline, gently forwardly convex along anterior margin where axis occupies just over 25 per cent of pygidial width. Axis very slightly convex (trs.) narrowing quite rapidly backwards to terminate about midlength of pygidium. Axial furrows faint and weaken posteriorly. Very faint axial ring furrow at just over 20 per cent axial length from anterior end. Pair of equally faint pleural furrows extend posterolaterally from where axial ring furrow meets dorsal furrow. Suggestion of a second furrow on right pleural field. Posterior border of pygidium declines steeply and shows indistinct terrace lines.

Discussion. Hughes (1979, p. 164) summarized the important differences between *Barrandia* and *Homalopteon*. Although the present specimen is poorly preserved it shows characteristics of the former listed by Hughes, in particular the unfurrowed glabella and weakly furrowed pygidium. Whittard (1961) described five species of *Barrandia* from the early Llanvirn of the Shelve Inlier, Shropshire, England. One of these, *B*. cf. *radians*, is now included in *Homalopteon* (Hughes 1979, p. 164). The Grangegeeth species is a relatively wide form; length to width ratio of the Irish specimen is 1:1·27 while the Shelve and Builth specimens range from 1:1·36 to 1:1.77 (measurements taken from plates of Whittard and Hughes but excluding 'narrow form' of *B. parabolica* Whittard, 1961 (pl. 33, fig. 6). The pygidial outline of the Irish species is semicircular with rather sharp anterolateral corners; this contrasts with the generally elliptical pygidial outlines of the Builth and Shelve species. The presence of *B*. sp. ?nov. in beds of early Caradoc age extends the range of this genus which was previously known to occur only up to the basal Caradoc (*N. gracilis* Biozone). Moreover, if our palaeogeographical interpretation is correct, it also extends the known geographical distribution of this genus outside the Anglo-Welsh area (Whittard 1961; Hughes 1979; Fortey and Owens 1987).

Family ILLAENIDAE Hawle and Corda, 1847
Subfamily ILLAENINAE Hawle and Corda, 1847
Genus ILLAENUS Dalman, 1827

Type species. *Entomostracites crassicauda* Wahlenberg, 1818, by subsequent designation; from the *Crassicauda* Limestone (Llandeilo), Fjäcka, Siljan, Sweden.

Illaenus sp.

Plate 1, fig. 17

1952 *Illaenus richardsoni* Reed; Harper, p. 107, pl. 5, fig. 6.
1980 *Illaenus* cf. *richardsoni* Reed; Romano, p. 66.
1980 *Illaenus* sp.; Romano, pp. 67–68.

Material. NMI F14032/A-B (the internal mould which was figured by Harper 1952, pl. 5, fig. 6 as 1951/17); LM 1988.216.447 and BM It.25704–It.25705.

Horizon and locality. NMI F14032 from Loc. 1; LM 1988.216.447 from Loc. 3; BM It.25704–It.25705 from Collon Quarry.

Discussion. Whilst Harper (1952) considered that his material agreed with Reed's (1914, p. 25) description of *I. richardsoni* from the Balclatchie and Lower Ardwell groups (lower Caradoc) at Girvan, he pointed out that it differed only from the Scottish specimens in having more clearly defined axial furrows. To Harper's observations may be added that the Irish cephalon is more strongly convex posteriorly (sag.) and has wider (trs.) free cheeks than Reed's material. We therefore consider it best be left in open nomenclature. A cranidium housed in the Royal Museum of Scotland (RMS-Geol 1870.12.950), was probably collected from the basal Knockerk House Sandstones Member and probably belongs in *Illaenus* sp. It is more elongate than the present figured specimen but this may be the result of deformation.

Fragmentary specimens of internal and external moulds of cranidia and free cheeks are here assigned to 'illaenid indet.' from the Tretaspis Bed and basal part of the Knockerk House Sandstones Member.

Family PROETIDAE Salter, 1864
Subfamily TROPIDOCORYPHINAE Přibyl, 1946
Genus DECOROPROETUS Přibyl, 1946

Type species. Proetus decorus Barrande, 1846, by original designation; from the Liteň Formation (Wenlock), Loděnice, Prague, Czech Republic.

Decoroproetus sp.

Plate 2, figs 11–13

1952 *Proetus ardmillanensis* Begg; Harper, p. 107, pl. 5, fig. 3.
1980 ?*Decoroproetus* sp.; Romano, pp. 68, 70.

Material. NMI F14026 (figured by Harper 1952, pl. 5, fig. 3 as NMI 1951/12); LM 1988.216.443–446 (445 and 446 are part and counterpart).

Horizon and locality. From small quarry at Loc. 26.

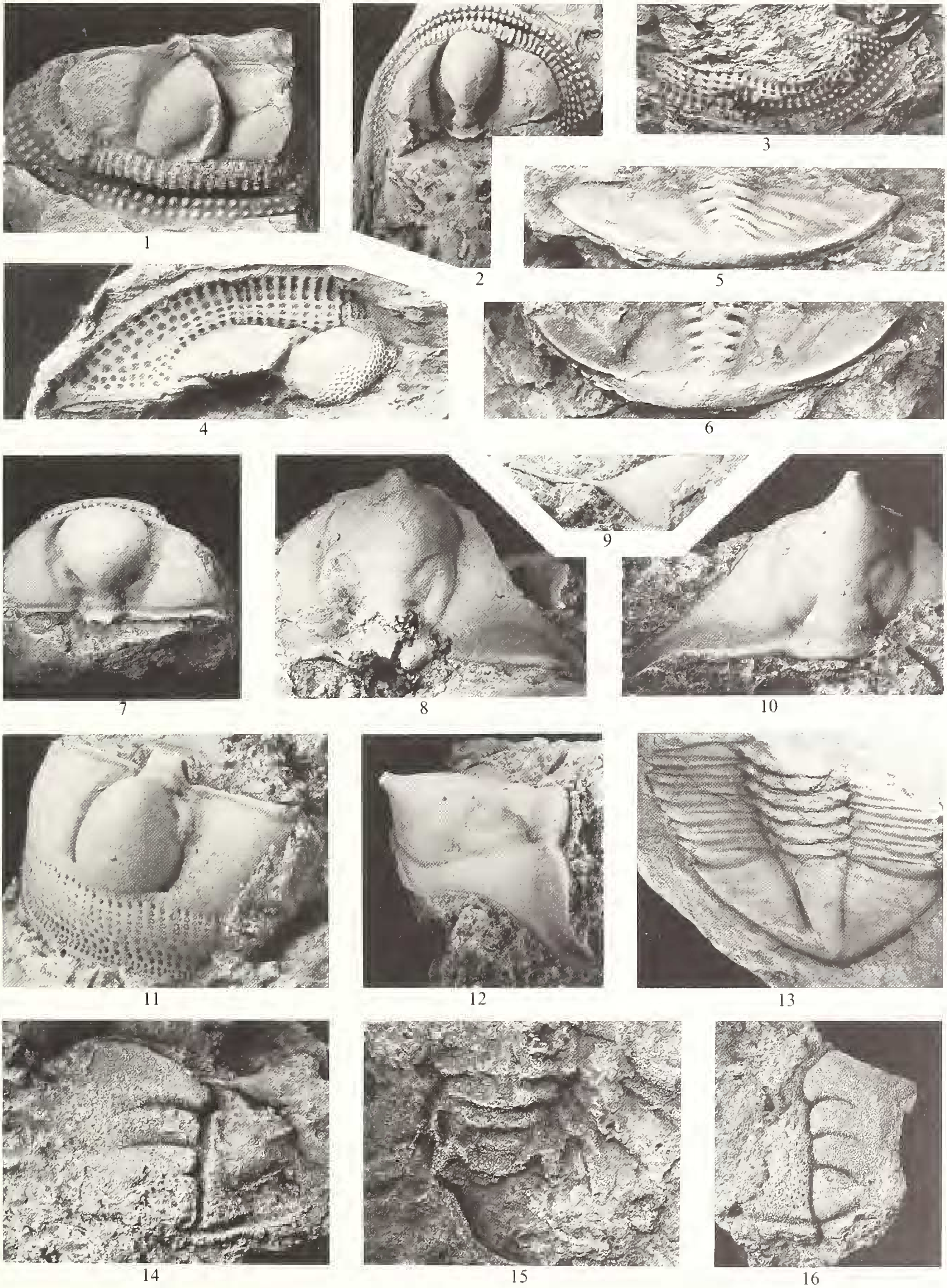
EXPLANATION OF PLATE 3

Figs 1–6. *Tretaspis* aff. *reticulata* Ruedemann, 1901. 1, NMI F20992; internal mould of cephalon, frontal view, ×3. 2, NMI F20993; internal mould of cephalon, dorsal view, ×2·5. 3, NMI F20994; internal mould of incomplete fringe, oblique frontal view, ×2·5. 4, NMI F20995; cast of external mould of incomplete cephalon, dorsal view, ×4. 5, NMI 20996/B; cast of external mould of pygidium, dorsal view, ×6. 6, NMI F20997; internal mould of pygidium, dorsal view, ×6. All from Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry.

Figs 7, 11. *Decordinaspis bispinosa* Harper and Romano, 1967. 7, NMI F20998; internal mould of cephalon, dorsal view, ×1·5. 11, NMI F20999; internal mould of cephalon, oblique frontal view, ×4. Both from concretions approximately 1 m above Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry.

Figs 8–10, 12–13. *Ampyx* aff. *repulsus* Tripp, 1976. 8, NMI F21000; internal mould of cranidium, dorsal view, ×2·5. 9, NMI F21001; internal mould of frontal part of glabella, lateral view, ×3. 10, 12, NMI F21002; internal mould of cranidium, dorsal and lateral views, respectively, both ×3. 13, NMI F21003; internal mould of damaged thorax and pygidium, dorsal view, ×2. 8–10, 12 from concretions approximately 1 m above Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry. 13 from ?Knockerk House Shales Member to basal Brickwork's Quarry Shales Member, Locality 26.

Figs 14–16. *Ceraurinella*? sp. 14, NMI F21004; internal mould of damaged cranidium, dorsal view, ×3. 15, NMI F21005; internal mould of damaged pygidium, dorsal view, ×3. 16, NMI F21006; internal mould of incomplete cranidium, dorsal view, ×2. All from basal Knockerk House Sandstones Member, Collon Quarry.



ROMANO and OWEN, *Irish Caradoc trilobites*

Discussion. Although the material is scant and poorly preserved, the specimens are best assigned to *Decoroproetus* Přibyl rather than *Astroproetus* Begg (see Owens 1973*b*) on account of the more evenly rounded glabella and lack of occipital lobes. The absence of striations however, is typical of *Astroproetus*. Harper (1952) identified the present form as *Proetidella ardmillanensis* (Begg, 1946), now referred to *Decoroproetus jamesoni* (Reed, 1914; see Owens 1973*a*, p. 46, pl. 8, fig. 11) from the Balclatchie Group, Girvan. As in the Grangegeeth cranidium the preglabellar area is long and occupies about 30 per cent of the sagittal cephalic length. However, the preglabellar field of the Irish cranidium is shorter than that of Begg's specimen.

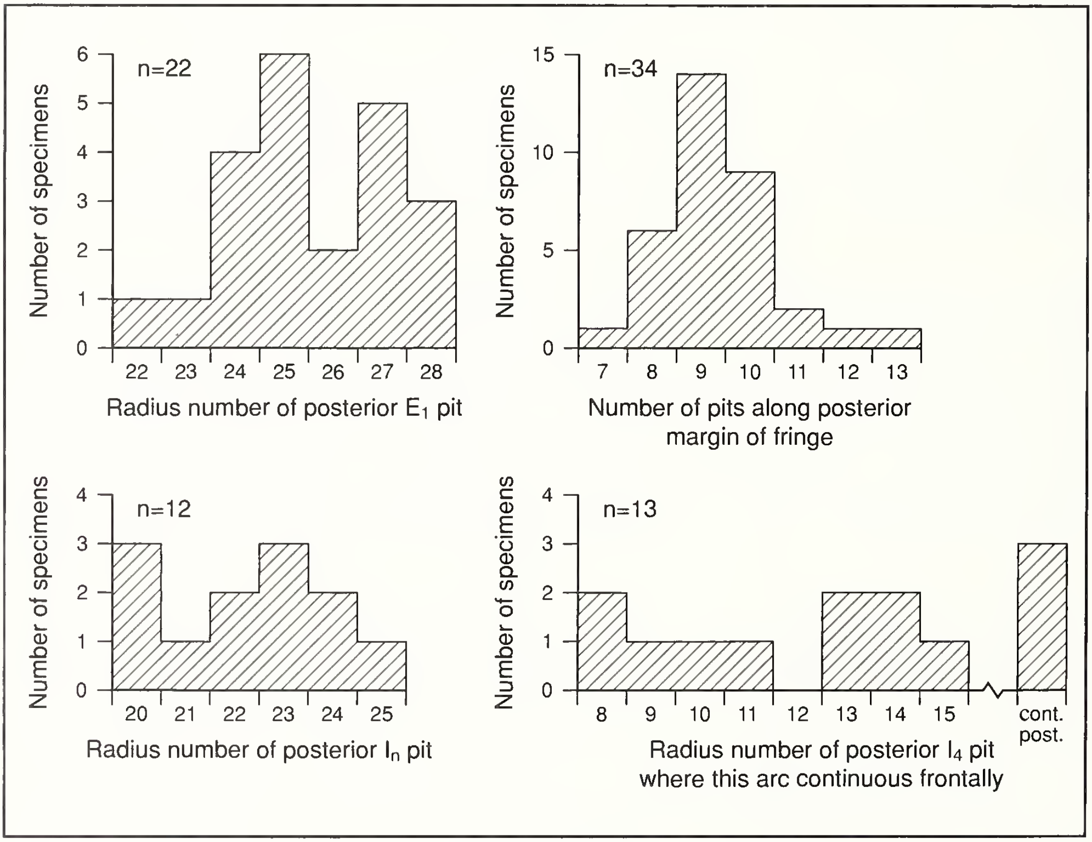
Family TRINUCLEIDAE Hawle and Corda, 1847
Subfamily TRINUCLEINAE Hawle and Corda, 1847
Genus TRETASPIS M'Coy, 1849

Type species. Asaphus seticornis Hisinger, 1840, by subsequent designation of Bassler (1915), from the Fjäcka Shale Formation (lower Ashgill) of Dalarna, Sweden.

Tretaspis aff. *reticulata* Ruedemann, 1901

Plate 3, figs 1–6; Text-fig. 4

1967 *Tretaspis kiaeri* (Størmer) subsp.; Brenchley *et al.*, p. 298.



TEXT-FIG. 4. Histograms showing the variation in selected fringe characteristics in *Tretaspis* aff. *reticulata* Ruedemann, 1901. Specimens from Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry.

1977 *Tretaspis*; Brenchley *et al.*, p. 74.
1980 *Tretaspis* sp.; Romano, pp. 68, 70.

Material. NMI F20992–F20997; BM It.25706–It.25716.

Horizon and locality. Tretaspis Bed and immediately overlying beds at Brickwork's Quarry, Loc. 26 and ?Loc. 190.

Description. This species is sufficiently abundant for the fringe pit statistics to be described. Arcs E_{1-2}, I_{1-3} and In complete, with pits arranged in a single set of radii with lists bounding I_2 and I_3. Few adventitious pits present on the genal prolongation. Arc E_1 contains 22·5–28·5 pits (mean 25·5, $N = 22$; half-fringe counts). E_2 has the same number of pits as E_1 in 2 (of 48) specimens, lacks the posterior pit in 41 specimens and the posterior two in 5 specimens. Three specimens (of 48) contain an adventitious E pit posteriorly. I_1 shares sulci with the E arcs anteriorly but becomes discrete on the lateral or even anterolateral part of the fringe. In I_n, 20–25 pits are present (mean 22·5, $N = 12$). A fifth I arc (I_4) is invariably present and is complete mesially in most specimens (16 of 19). In the remaining specimens up to two pits (half-fringe) are missing mesially. Three of 14 specimens show the arc extending to the posterior margin; the remainder containing 4–15·5 pits. Specimens with I_4 complete mesially have at least 7 pits in this arc. Seven to 13 pits present along the posterior margin of the fringe (mean 9, $N = 34$).

Discussion. The Grangegeeth *Tretaspis* belongs in the *T. sagenosa* Group of Owen (1980, p. 718), the typical representatives of which are Laurentian mid-Llandeilo to early Caradoc species having a broad fringe and high peripheral pit count. The group gave rise to the European *T. moeldenensis* Group in the late Caradoc (Owen 1980, 1987) and was discussed recently by Ingham and Tripp (1991, p. 41).

The Irish species is closest to the broadly contemporaneous *T. reticulata* Ruedemann (see also Whittington 1941, pl. 6, figs 26–27, 31; Stäuble 1953, figs 21–24) from the Rysedorph Conglomerate (probably Blackriveran) of New York. Ruedemann's species is based on a limited amount of poor material, but the fringe pitting of the Irish material seems to encompass that of *T. reticulata*, and the only distinguishing features of the Grangegeeth specimens are the more pronounced cephalic brim and possibly longer eye ridges. A specimen included in *T. reticulata* by Whittington (1941, pl. 6) from probable Blackriveran strata near Tenth Legion, Virginia has a well-developed brim as does one from the Lower Balclatchie Group at Girvan figured as *T.* cf. *reticulata* by Ingham and Tripp (1991, fig. 8*d–e*). The Grangegeeth form differs from both of these in its slightly lower E_1 pit count (up to 28·5 compared with about 32 and 29·5, respectively).

All the above forms have the pits in I_4 distinct from those in I_n, even in those specimens of *T.* aff. *reticulata* where the arc is short. In *T. sagenosa* Whittington (1959, p. 448, pls 24–27, pl. 28, figs 1–8) from the lower Edinburg Formation (early Caradoc), this arc is restricted to a few pits situated very close to those of I_n in front of the axial furrow. *T.* aff. *reticulata* also differs from Whittington's species in consistently lacking E_3 pits (present in a few specimens of *T. sagenosa*), in having the lateral eye tubercles situated farther forward and closer to the glabella and in having fewer large apodemes on the pygidial axis.

T. canadensis Stäuble (1953, p. 203, figs 17–20, 22) from a debris flow in the early Caradoc Citadel Formation in Quebec City, Canada and *T. eximia* Ingham and Tripp (1991) from the mid-Llandeilo at Girvan, Scotland have arc I_4 invariably complete and I_5 developed anteriorly. The latter also has a complete E_3 arc and a very short eye ridge.

Genus DECORDINASPIS Harper and Romano, 1967

Type species. Decordinaspis bispinosa Harper and Romano, 1967, by monotypy; from the Brickwork's Quarry Shales Member, Knockerk Formation of early Caradoc age; Grangegeeth, Co. Meath, eastern Ireland.

Decordinaspis bispinosa Harper and Romano, 1967

Plate 3, figs 7, 11

*1967 *Decordinaspis bispinosa* nov. sp.; Harper and Romano, p. 305, pl. 8, figs 1–2, pl. 9, figs 1–4 [described].
1967 *Decordinaspis bispinosa* Harper and Romano; Brenchley *et al*., p. 298 [listed only].
1975 *Decordinaspis bispinosa* Harper and Romano, 1967; Hughes *et al*., p. 566, p. 5, figs 59–63.
1980 *Decordinaspis bispinosa* Harper and Romano; Romano, p. 68.

Material. Holotype: NMI G.104/1965 (Harper and Romano 1967, pl. 8, figs 1–2). Paratype: NMI G.105/1965 (Harper and Romano 1967, pl. 9, figs 1–3) (see also Hughes *et al.* 1975, pl. 5, figs 59–62); NMI F20998, F20999; BM It.25717–It.25719.

Horizon and locality. Concretions and enclosing shale just above the Tretaspis Bed, Brickwork's Quarry.

Discussion. Following the discovery of further specimens, minor additional comments can be added to the description given in Harper and Romano (1967). The largest specimen now known is approximately *c.* 30 mm across the posterior border of the cephalon. The S1 furrows are sometimes slightly larger than S2 and in some specimens the former are continuous with the occipital furrow. The shape of S1 is variable but does not appear to be related to maturity; it also varies either side of the glabella in a single specimen. On the internal moulds of three new specimens a very faint eye ridge is present, directed slightly forwards from the lateral eye tubercle towards S3, where it terminates in the axial furrow (this feature is known in *Tretaspis* and reedolithines but not in *Nankinolithus* with which *Decordinaspis* has also been thought to have affinities—see Hughes *et al.* 1975, p. 566). The fossulae situated in the axial furrows adjacent to the fringe are larger and more pronounced than in the original material.

Decordinaspis has been recorded from the Upper Tramore Volcanic Formation at Kilbride in southeast Ireland where the associated rich brachiopod fauna is closely comparable with that of the Ballymoney Formation at Courtown, of Harnagian to Soudleyan age (Mitchell *et al.* 1972; Carlisle 1979). More recent extensive collecting by Dr M. Parkes has failed to confirm the presence of *Decordinaspis* here (Parkes 1990) although another trinucleine is present and is currently under investigation by one of us (A.W.O.) and Parkes. It may be this which was identified earlier as *Decordinaspis*.

Family RAPHIOPHORIDAE Angelin, 1854
Genus AMPYX Dalman, 1827

Type species. Ampyx nasutus Dalman, 1827, by monotypy; neotype described by Whittington (1950, p. 554) from the *Asaphus* Limestone, upper Arenig of Östergötland, Sweden.

Ampyx aff. *repulsus* Tripp, 1976

Plate 3, figs 8–10, 12–13

1967 *Ampyx* sp. cf. *A. costatus* Angelin; Brenchley *et al*., pp. 298, 302, pl. 7, figs 1–3.
1980 *Ampyx* sp.; Romano, pp. 68, 70.

Material. NMI F21000–F21003; NMI G.109/1965 and NMI G.110/1965 (figured in Brenchley *et al.* 1967, pl. 7, figs 1–3); BM It.25720–It.25724.

Horizon and locality. Loc. 208 and ditch section at Loc. 26. Tretaspis Bed and concretions immediately above; Brickwork's Quarry.

Discussion. This material is close to a number of species listed by Tripp (1976, p. 393) as being typified by *A. mammillatus* Sars, including: *A. virginiensis* Cooper, 1953, *A. repulsus* Tripp, 1976, *A. americanus* Safford and Vogdes, 1889 and *A. incurvus* Reed, 1906. To this list may be added *A. austinii* Portlock, 1843 redescribed by Owen *et al.* (1986) from the upper Caradoc Raheen Formation of Co. Waterford. Tripp listed the distinguishing features of this species-group as being the short glabella with steep anterior slope, strongly developed second muscle scars and broad posterior border furrows. The Grangegeeth form is closest to *A. repulsus* from the basal Superstes Mudstones (middle Llandeilo) at Girvan, southwest Scotland, differing only in having a more steeply descending glabella to the anterior border, a smooth rather than shallowly pitted cephalic and pygidial surface and in the pygidial segmentation being a little more obvious. The more steeply descending glabella in front of the glabellar spine, narrower anterior part of the fixed cheek, less sigmoidal facial suture and longer pygidium distinguish it from *A. virginiensis* Cooper, 1953 (p. 15, pl. 7, figs 1–11, 18), from the lower Edinburg Formation (lower Caradoc). The glabellar proportions are similar to those of *A. hornei* Etheridge and Nicholson, (*in* Nicholson and Etheridge 1879; see Reed 1906, pl. 3, figs 8–9, and Tripp 1980, pl. 3, figs 8–9) from the lower Caradoc Balclatchie Group at Girvan, but the Scottish species has a well-developed pair of genal ridges. *A. aff. repulsus* is similar to *A. austinii* Portlock but its shorter glabella is again diagnostic.

Family CHEIRURIDAE Hawle and Corda, 1847
Subfamily CHEIRURINAE Hawle and Corda, 1847
Genus CERAURINELLA Cooper, 1953

Type species. Ceraurinella typa Cooper, 1953, by original designation; from the *Echinosphaerites* beds of the Edinburg Limestone of early Caradoc age, Shenandoah Valley, Virginia, USA.

Ceraurinella? sp.

Plate 3, figs 14–16

1980 *Ceraurinella* sp; Romano, p. 67.

Material. NMI F21004–F21006.

Horizon and locality. Loc. 1.

Discussion. Though incomplete, the material shows closest affinies with species placed in *Ceraurinella* although the closely related upper Ordovician genus *Xylabion* Lane, 1971, also includes species with some similar features to those found in the Grangegeeth form. The pygidium of the Irish form differs from that of *C. typa* Cooper, 1953 (see Whittington and Evitt 1954) in that the second pair of spines is directed more outwards and there is no third pair of spines. In some of the figured pygidia of *C. nahanniensis* Chatterton and Ludvigsen, 1976 (p. 55, pl. 9, especially figs 13, 15, 19) the third pair of spines are rudimentary and terminate well in front of the second pair. This condition approaches that present in the single poorly preserved pygidium from Collon.

The two figured cranidia of *Ceraurinella*? sp. show differences in the length of the glabellar furrows, shape of L1 and shape of the frontal glabellar lobe. These might reflect basic morphological differences but more probably are the result of deformation.

Subfamily DEIPHONINAE Raymond, 1913
Genus SPHAEROCORYPHE Angelin, 1854

Type species. Sphaerocoryphe dentata Angelin, 1854, by subsequent designation of Vogdes (1890); from the upper Ordovician of Sweden.

Sphaerocoryphe cf. *pemphis* Lane, 1971

Plate 4, figs 1–3

1967 *Sphaerocoryphe thomsoni* (Reed); Brenchley *et al.*, pp. 298, 302, pl. 7, figs 5–6.
?1980 *Sphaerocoryphe* sp. indet.; Romano, p. 67.
1980 *Sphaerocoryphe* cf. *thomsoni* (Reed); Romano, p. 69.

Material. NMI F14064 (= NMI G.106/1965 of Brenchley *et al.* 1967, pl. 7, figs 5–6), NMI F21007–F21008; BM It.25725–It.25728.

Horizon and locality. Most specimens are from the Tretaspis Bed, Brickwork's Quarry; some of the material is possibly from the base of the Knockerk House Sandstones Member, Collon Quarry.

Discussion. The Grangegeeth species possesses two pairs of secondary spines on the fixed cheeks, a feature shared with Llandeilo to Ashgill species such as *S. dentata* Angelin, 1854 (= *S. thomsoni* Reed, 1906; see Kielan-Jaworowska *et al.* 1991), *S. pemphis* Lane, 1971, *S. kingi* Ingham, 1974, *S. punctata* Angelin, 1854, ?*S. atlantiodes* Öpik, 1937, *S. ludvigseni* Chatterton, 1980, and *S. murphyi* Owen *et al.*, 1986. The presence of such spines would appear to be a useful feature in identifying species-groups but, as pointed out by Owen and Bruton (1980, p. 28), Shaw's (1968) work showed this to be a variable feature. However, of these species, the Grangegeeth form appears closest to *S. pemphis* from the lower Caradoc Balclatchie and Lower Ardwell groups at Girvan, differing mainly in details of the profixigenal spines. In particular those of the Grangegeeth species are not separated by a short straight lateral margin and the posterior branch of the facial suture does not cut the base of the anterior spine as it does in the Girvan species.

The specimens from the Knockerk House Sandstones Member are too incomplete to allow specific identification, but the bulbous frontal glabellar lobe is similar in size and proportions to *S.* cf. *pemphis* in the overlying Brickwork's Quarry Shales Member. The sculpture on the Knockerk House Sandstones glabellae appears to be more reticulate than granular, but the specimens are provisionally referred to the Brickwork's Quarry Shales form.

EXPLANATION OF PLATE 4

Figs 1–3. *Sphaerocoryphe* cf. *pemphis* Lane, 1971. 1, NMI F21007; internal mould of cephalon, dorsal view. 2, NMI G106.1965 (figured by Brenchley *et al.* 1967, pl. 7, figs 5–6); internal mould of cephalon, dorsal view. 3, NMI F21008; cast of external mould of pygidium, dorsal view. All from Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry. All ×3.

Fig. 4. *Sphaerexochus* sp. indet. NMI F21009; internal mould of incomplete cranidium, lateral view; horizon and locality as above, ×3.

Fig. 5. *Acanthoparypha*? sp. NMI F21010; internal mould of incomplete cranidium, oblique lateral view; horizon and locality as above, ×3.

Fig. 6. Cybelinae indet. cf. '*Deacybele*' *pauca* Whittington, 1965. NMI F21011; internal mould of incomplete cranidium, dorsal view; Tretaspis Bed, Brickwork's Quarry Shales; Brickwork's Quarry, ×4.

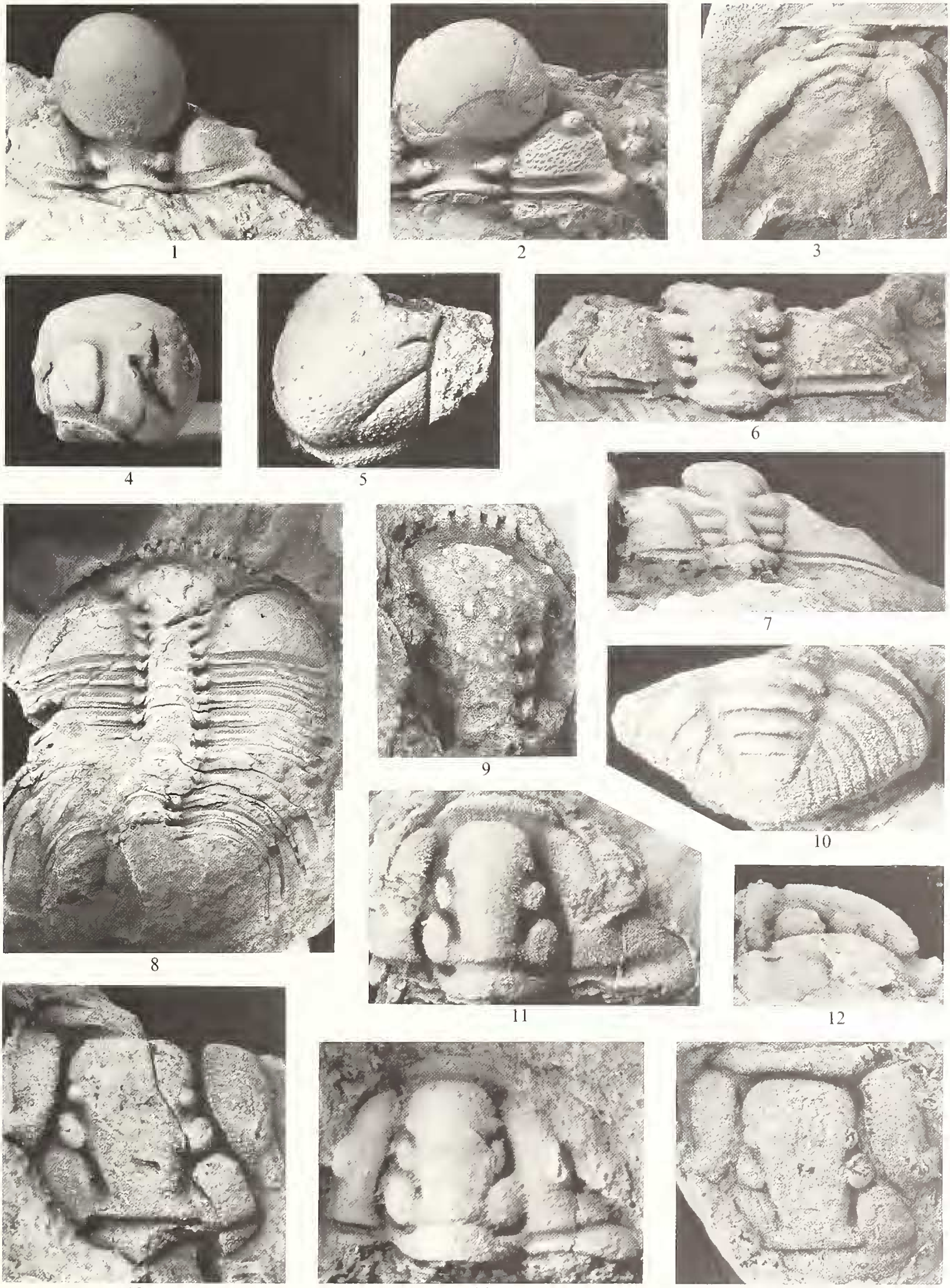
Fig. 7. Cybelinae indet. LM 1988.216.452; internal mould of incomplete cranidium, dorsal view; ?Knockerk House Shales Member; Loc. 38, ×3.

Figs 8, 9. *Atractopyge*? sp. 8, GSI F000879 (figured by Harper 1952, pl. 5, fig. 1 as GSI/JCH 1); internal mould of incomplete individual, dorsal view, ×1·5. 9, NMI F14024/B; internal mould of incomplete cranidium, dorsal view, ×4. Basal Knockerk House Sandstones Member; Locs 1 and 3 respectively.

Figs 10–12, 14. *Flexicalymene* sp. ?nov. 10, NMI F21012; internal mould of pygidium, dorsal view. 11–12, 14, NMI F21013; 11–12, internal mould of damaged cranidium, dorsal and lateral views; 14, cast of external mould, dorsal view. All from Tretaspis Bed, Brickwork's Quarry Shales Member; Brickwork's Quarry. All ×6.

Figs 13, 15. *Gravicalymene* sp. NMI F21014; internal mould and cast of external mould of incomplete cranidium, dorsal views; Basal Knockerk House Sandstones Member; Collon Quarry, ×3.

PLATE 4



ROMANO and OWEN, *Irish Caradoc trilobites*

Subfamily SPHAEREXOCHINAE Öpik, 1937 (emend. Lane and Owens 1982, p. 52)
Genus SPHAEREXOCHUS Beyrich, 1845

Type species. Sphaerexochus mirus Beyrich, 1845, by monotypy; from the Wenlock of Bohemia.

Sphaerexochus sp. indet.

Plate 4, fig. 4

1980 *Sphaerexochus* sp. indet.; Romano, p. 69.

Material. NMI F21009.

Horizon and locality. Concretion approximately 1 m above the Tretaspis Bed, Brickwork's Quarry.

Discussion. Sphaerexochus is common in the Girvan area (see Tripp *in* Williams 1962) from where Tripp figured species from the confinis Flags (1962), Albany mudstones (1965), Stinchar Limestone (1967, 1979), and Superstes Mudstones (1976). Tripp commented on the extreme variability within some of these species, particularly in the length/width proportions of the glabella. The relatively wide glabella of the Irish specimen is a feature of all of the above Scottish species and, in view of Tripp's comments, clearly cannot be used as a diagnostic characteristic. The three pairs of glabellar furrows in the present specimen, is a feature mentioned by Tripp for his species *S. eurys* and *S. arcuatus*, from the confinis Flags and Superstes Mudstones respectively. There is also a suggestion of such structures in the Stinchar Limestone species *S. filius* Tripp, 1979 (pl. 38, fig. 18). As Tripp remarked (1976, p. 400), these three Scottish species may only be reliably distinguished by their pygidial characteristics and until more complete Irish material is recovered it would seem preferable to leave the specimen in open nomenclature.

Genus ACANTHOPARYPHA Whittington and Evitt, 1954

Type species. Acanthoparypha perforata Whittington and Evitt (1954, p. 72), by original designation; from the Edinburg Limestone (early Caradoc) of Virginia, USA.

Acanthoparypha? sp.

Plate 4, fig. 5

1980 *Acanthoparypha* sp.; Romano, p. 69.

Material. NMI F21010.

Horizon and locality. Concretion approximately 1 m above the Tretaspis Bed, Brickwork's Quarry.

Discussion. Following Whittington and Evitt (1954, p. 71), the absence of an occipital spine would preclude this cranidium from being assigned to *Nieskowskia* Schmidt, 1881, although Lane (1971, p. 66) pointed out that this is a variable feature. The Grangegeeth form differs from the type species of *Acanthoparypha*, *A. perforata*, in possessing smaller tubercles, a more parallel-sided glabella, and less even longitudinal convexity to the glabella (cf. Whittington and Evitt 1954, pl. 14, fig. 17; pl. 15, fig. 11). It is closer to *A. chiropyga* Whittington and Evitt, 1954, from the Lincolnshire Limestone of Virginia, but is again distinguishable by its less tapered glabellar outline, more triangular basal glabellar lobes and longitudinal convexity (cf. Whittington and Evitt, 1954, pl. 29, fig. 6). Tripp (1967, p. 63) assigned a specimen to *Acanthoparypha* sp. from the upper Stinchar Limestone at Girvan. Tripp did not figure the single incomplete cranidium, but the stated weak convexity of the glabella is unlike that seen in the Irish species. The specimen figured as *Acanthoparypha* or *Pandaspinapyga* sp. by Tripp (1979, pl. 38, fig. 20) differs from the present species in having more curved S1. Lane and Owens (1982, p. 55) considered these two genera to be possibly synonymous. A Shropshire species, *A. stubblefieldi* (Bancroft) from the Harnagian Smeathen Wood Beds has a characteristic bend in S1 and relatively longer S2 and S3; also the glabella is only moderately convex longitudinally (Dean 1961, pl. 49, figs 3–6, 11).

Family ENCRINURIDAE Angelin, 1854
Subfamily CYBELINAE Holliday, 1942

Cybelinae indet. cf. '*Deacybele*' *pauca* Whittington, 1965

Plate 4, fig. 6

1980 *Deacybele* cf. *pauca* Whittington; Romano, p. 69.

Material. NMI F21011; BM It.25729–It.25730.

Horizon and locality. NMI F21011 and BM It.25729 from the Tretaspis Bed; BM It.25730 from concretions approximately 1 m above the Tretaspis Bed, Brickwork's Quarry.

Discussion. The status of *Deacybele* and its separation from *Cybeloides* Slocum, 1913 has been questioned but remains unresolved (Owen 1981; Owen and Romano *in* Harper *et al*. 1985; Owen *et al*. 1986). The following discussion is restricted to comparisons with other species which do not show coalescence of the glabellar lobes. The Grangegeeth species is very close to '*D.*' *pauca* Whittington, 1965, differing only in the relatively longer frontal glabellar lobe of the Bala specimens (though the Irish specimen is imperfectly preserved), and more pedunculate eye of the Irish specimen (presence of genal spines in the present material is unknown). '*D.*' *pauca* occurs in the Gelli-grîn Calcareous Ashes of early Longvillian age. Other similar species are '*D.*' *gracilis* Nikolaisen, 1961 (see Owen and Bruton 1980, pl. 8, figs 14–16) from the late Caradoc Solvang Formation ('Upper Chasmops Limestone') of Norway, and 'Cybelinae cf. '*C.*' *mchenryi* Reed' (Owen *et al*. 1986, p. 108, figs 49–51) from the upper Caradoc Raheen Formation of southeast Ireland. In the Norwegian and Raheen species, the eyes are more posteriorly placed, while in the Raheen form the frontal lobe and posterior border are longer (sag. and exs.).

Cybelinae indet.

Plate 4, fig. 7

1952 *Cybele* cf. *revaliensis* Schmidt; Harper, p. 89.
1980 *Deacybele* sp.; Romano, p. 67.

Material. LM 1988.216.452–453 (part and counterpart).

Horizon and locality. Loc. 38.

Discussion. This form differs from cf. '*Deacybele*' *pauca* in the following details: the cranidium is proportionally wider, the lateral glabellar lobes are longer (trs.) and median lobe narrower, the apodemes in the occipital furrow posterior to L1 are less well marked, the palpebral lobes are level with S2, the cheeks are pitted, and the glabella is probably smooth; the posterior borders widen (exs.) considerably abaxially. There is also a ?short, slim genal spine and a small elongate (sag.) indentation situated on the anterior slope of the frontal glabellar lobe. The large lateral glabellar lobes, more anteriorly placed palpebral lobes, and presence of genal spines serve to distinguish this form from *Atractopyge revaliensis* Schmidt, 1881 (pl. 13, figs 20*a*–*b*) from the upper Llanvirn and Llandeilo of the Baltic area.

The large lateral glabellar lobes, the possible presence of a median pit or depression on the frontal lobe, and the suggestion of an incipient branching of S3 (?caused by the presence of two apodemes in this furrow) may indicate that this cranidium belongs in *Stiktocybele* Ingham and Tripp, 1991, a genus founded on their new species *S. bathytera* from the Llandeilo Doularg Formation at Girvan.

It is differentiated from all other cybelines by the presence of 13 thoracic segments, the seventh of which is macropleural. It shares with *Cybelurus* Levitskiy, 1962 and *Lyrapyge* Fortey, 1980 the presence of a deep cleft on the frontal glabellar lobe. Ingham and Tripp (1991) also included '*Cybele*' *balclatchiensis* Reed, 1914 from the Balclatchie Group at Girvan in *Stiktocybele* (see Tripp 1980, p. 131 for full synonymy). The Grangegeeth form is provisionally distinguished from both species by its considerably more slender genal spine.

Genus ATRACTOPYGE Hawle and Corda, 1847

Type species. *Calymene? verrucosa* Dalman, 1827, by monotypy; probably from the Crûg Limestone (Ashgill) of South Wales (see Dean 1974; Price 1984).

Atractopyge? sp.

Plate 4, figs 8–9

1952 *Cybele* (*Cybelella*) cf. *rex* (Nieszkowski); Harper, pp. 88, 106, pl. 5, fig. 1.
1980 *Cybellela* cf. *rex* (Nieszkowski); Romano, pp. 66–67.
1988 *Cybellela* cf. *rex* (Nieszkowski, 1857); Morris, p. 64.

Material. GSI:F00879 (figured as GSI/JCH by Harper 1952, pl. 5, fig. 1); NMI F14024/a–b; LM 1988.216.403).

Horizon and locality. GSI:F00879 from Loc. 1; F:14024 and LM 1988.216.403 from Loc. 3; other material from Collon Quarry.

Discussion. This material was originally referred to *Cybellela* Reed, 1928, a genus which was maintained by Whittington (1965, p. 43) having earlier been placed in the synonymies of *Cybele* (by Öpik 1937) and *Atractopyge* (by Henningsmoen *in* Moore 1959). Dean (1971*a*, 1974) redescribed the type species of the latter genus, *A. verrucosa*, and suggested that two of the species retained in *Cybellela* by Whittington ('*C.*' *aspera* and '*C.*' *dentata*) might best be reassigned to *Atractopyge*, leaving only *C. rex* Nieszkowski, 1857 (the type species) and *C. coronata* Schmidt, 1881 in Reed's genus. Both species, from the middle Ordovician of Estonia, are in need of redescription. Ludvigsen (1979, p. 47) tentatively ascribed a new species, *C.*? *thor*, from the middle Ordovician of western Canada to *Cybellela*, but noted its similarity to other cybeline genera. Preliminary results of a multivariate study of the Cybelinae by one of us (A.W.O.) and R. P. Tripp suggest that the Baltic species of *Cybellela* fall well within the range of *Atractopyge*, and *C.*? *thor* is closest to *Bevanopsis* Cooper, 1953. The Grangegeeth material is therefore provisionally placed in *Atractopyge*.

A.? sp. closely resembles the illustrations by Schmidt (1881) of '*Cybele*' *rex* and '*C.*' *coronata* in gross cranidial and glabellar proportions and in possessing a long (sag., exs.) spinose preglabellar area. Both Baltic species require redescription before detailed comparison can be made. The long, spinose cranidial border of *A.*? sp. distinguishes it from *A. condylosa* Dean, 1971*b*, from the Llandeilo–lowest Caradoc of Newfoundland, *A. michelli* Reed, 1914 (see Morris and Tripp 1986; Tripp 1980) from the Balclatchie and Lower Ardwell groups at Girvan, and *A. killochanensis* Tripp, 1954, from the Kiln Mudstones (Upper Ardwell Group). The frontal lobe is a little more expanded (trs.) than that of *A. michelli*, but less so than those of *A. condylosa* and especially *A. killochanensis*. The anterior cranidial border, absence of prominent paired glabellar tubercles and larger glabellar lobes distinguish the Grangegeeth species from *A. petiolulata* Tripp, 1976, from the Llandeilo at Girvan (see also Ingham and Tripp 1991, fig. 14*l*).

Family CALYMENIDAE Milne Edwards, 1840
Subfamily FLEXICALYMENINAE Siveter, 1977
Genus FLEXICALYMENE Shirley, 1936

Type species. Calymene Blumenbachii var. *Caractaci* Salter, 1865, by original designation; from the Woolstonian and Marshbrookian (mid-Caradoc) of south Shropshire, England.

Flexicalymene sp. ?nov.

Plate 4, figs 10–12, 14

1967 calymenid; Brenchley *et al.*, p. 298.
1980 ?*Onnicalymene* sp.; Romano, p. 69.

Material. NMI F21012–F21013; BM It.25731–It.25733.

Horizon and locality. Tretaspis Bed; Brickwork's Quarry.

Description. Cranidium about twice as wide as long. Preoccipital glabella about as wide as long, subparabolic in outline with only very gently rounded or blunt-ended anterior margin and nearly straight lateral margins anterior to L1. Glabella moderately convex transversely; in longitudinal profile it curves evenly forwards from about level with S1 to anterior part of frontal lobe, then nearly vertically to preglabellar furrow. Occipital ring longest mesially, narrowing gradually abaxially behind L1; near axial furrows there is slight development of nodes. In lateral view occipital ring is gently convex. Behind median lobe occipital furrow transversely straight, symmetrical in cross-section (sag.) and fairly shallow; behind L1 it swings posteriorly a little and deepens. L1 large, subrectangular in outline slightly longer than wide and just over 25 per cent basal width of glabella. L2 suboval in outline, highest adaxially and sloping steeply downwards anteriorly; just over half the length (exs.) of L1. L3 small, elongate (trs.), about half the length (exs.) of L2. S1 shallow from occipital furrow over adaxial neck of L1; deepening and turning abaxially to anterolateral corners of L1 where directed outwards and forwards to meet axial furrow. Short anterior branch of S1 crosses inner neck of L2. S2 shallower than S1, abaxially more transverse, adaxially turn rearwards around L2. S3 short, narrower (exs.) than S2, barely reach axial furrows. Frontal glabellar lobe with nearly straight anterior margin, three times as wide as long, level with or just projecting beyond fixed cheeks. Axial furrows deep, curved around L1, then converge evenly forwards at about 35° to join with transverse preglabellar furrow. Shallow anterior pits in axial furrows just anterior to S3. In lateral view preglabellar furrow passes quite sharply into upturned, convex (sag.) 'anterior border' (see Ingham 1977, p. 90 for discussion of the problem of terminology and homology of the preglabellar area in calymenids). Anterior margin gently curved in dorsal view, quite strongly arched in frontal view. Posterior border increases in width (exs.) abaxially; posterior border furrows of constant width, dying out before reaching margins of fixed cheeks. Fixed cheeks gently convex transversely, slope more steeply anteriorly. Posterior end of palpebral lobes opposite anterior of L1, anterior end level with middle to anterior end of L2. Anterior branch of facial suture continues forwards in very broad curve to anterior margin. Posterior branch directed very gently abaxially forwards then bends evenly posterolaterally to cranidial margin.

Free cheeks, hypostoma and thorax unknown. Pygidium just under twice as wide as long, and two and a half times as wide as axis. Axis approximately 80 per cent length of pygidium; with five or six axial rings and terminal piece. Axial rings of approximately constant width (sag. and exs.) separated by wide ring furrows one to four; furrows five and six are indistinct. Axial furrows distinct except around terminal piece. Pleural regions with five pairs of pleural furrows and four (?five) pairs of interpleural furrows. Pleural furrows widest (exs.) and deepest adaxially, dying out at steeply downturned pygidial border. First pair extend onto smooth pleural facet. Interpleural furrows fainter, especially proximally, and longer than pleural furrows. Anterior pleural bands narrower than posterior bands, particularly on more anterior pleurae. Sculpture of cranidium and pygidium granulate except in deepest parts of furrows.

Discussion. The short preglabellar area and posteriorly placed eyes of this form prompted Romano's (1970) generic placement; it was later only tentatively so assigned (Romano 1980). The status of *Onnicalymene* has been questioned by Siveter (1977), who retained it as a subgenus of *Flexicalymene*. Ingham (1977) regarded it as a junior synonym of *Flexicalymene* which has been followed by Owen and Bruton (1980) who suggested that the informal term '*onniensis* species group' would be sufficient to characterize those species previously assigned to *Onnicalymene*. The Grangegeeth form clearly is best assigned to *Flexicalymene* (*sensu* Siveter 1977, p. 353). The short preglabellar area, fairly sharp change in slope from the 'preglabellar furrow' to 'anterior border', posteriorly placed eyes, narrow anterior portion of fixed cheeks and straight sides to the glabella serve to distinguish this species from other forms of this genus. *Flexicalymene* sp. ?nov. is fairly close to *Flexicalymene shirleyi* Tripp, 1954, from the Kiln Mudstones, middle Caradoc, of Craighead Quarry, Girvan, but the Grangegeeth form has a more gentle longitudinal curvature to the cranidium, a proportionately longer glabella, more posteriorly placed eyes and fewer pygidial axial rings.

Genus GRAVICALYMENE Shirley, 1936

Type species. *Gravicalymene convolva* Shirley, 1936, by original designation; from the Birdshill Limestone (Pusgillian) of Llandeilo, south central Wales.

Gravicalymene sp.

Plate 4, figs 13, 15

1980 ?*Flexicalymene* sp.; Romano, pp. 65, 67.

Material. NMI F21014; BM It.25734–It.25735.

Horizon and locality. BM It.25734 from Loc. 210B; others from Collon Quarry.

Discussion. The bell-shaped glabella, unconstricted axial furrows (Ingham 1977, p. 94) and subquadrate form of the glabella in front of L2 (Siveter 1977, p. 383) indicate that the Irish form should be assigned to *Gravicalymene*. The material differs from the type species in having a relatively wider base to the glabella, straighter anterior margin to the frontal lobe and narrower (sag.) 'anterior border'. It differs from *G. jugifera* Dean, 1962 (p. 116, pl. 14, figs 3–4, 8–9) from the Pusgillian of Cross Fell, northern England, in its straighter anterior margin to the frontal lobe and narrower preglabellar furrow. *G. deani* Ingham, 1977 (p. 96, pl. 20, figs 16–17; pl. 21, figs 1–6) from the Cautleyan of Cautley, northern England, is similar to *Gravicalymene* sp. in having strongly sigmoidal axial furrows and a very broadly rounded or nearly straight anterior margin to the frontal lobe. The Irish form differs from *G. deani* in its much less thickened (sag.) 'anterior border'. Of the two Caradoc species of *Gravicalymene* from south Shropshire, *Gravicalymene* sp. contrasts with the holotype of *G. praecox* (Bancroft, 1949) (see Dean 1963, p. 225, pl. 39, figs 1, 3, 9, 12–14), which is an immature cranidium, in its longer frontal glabellar lobe. The mature specimens of *G. praecox* are poorly preserved and difficult to compare with the Irish material. The other Shropshire species *G. inflata* Dean, 1963 (p. 227, pl. 39, fig. 6) is only known from a single cranidium but the considerable width (trs.) of the anterior part of the fixed cheek serves to distinguish it from *Gravicalymene* sp. *Gravicalymene capitovata* Siveter, 1977 (p. 377, figs 11A–H, figs 12A, E–I, K–L) from the uppermost Llanvirn Engervik Member of the Elnes Formation ('*Ogygiocaris* Shale ($4a\alpha_3$)'; see Owen *et al*. 1990), of the Oslo Region has a relatively much larger L1 and longer 'anterior border' than *Gravicalymene* sp.

Ross (1967, 1979) figured a number of species of *Gravicalymene* from the Caradoc of Kentucky and Ohio, USA. The Irish form differs from these American species in its longer frontal glabellar lobe and narrower (sag. and exs.) 'anterior border'.

Family PTERYGOMETOPIDAE Reed, 1905
Subfamily PTERYGOMETOPINAE Reed, 1905
Genus ACHATELLA Delo, 1935

Type species. *Dalmanites achates* Billings, 1860, by original designation; from the Cobourg beds (upper Caradoc) of Ottawa, Ontario, Canada.

Achatella truncatocaudata? (Portlock, 1843)

Text-fig. 5A, F

1980 ?*Achatella* cf. *truncatocaudata* (Portlock); Romano, p. 67.

Material. GSI F00880 (figured by Harper 1952, pl. 5, fig. 5); BM It.25741.

Horizon and locality. GSI F00880 from Loc. 1; BM It.25741 from Collon Quarry.

Discussion. The Grangegeeth specimens differ from *A. truncatocaudata* from the Killey Bridge Formation (Cautleyan) of Pomeroy, Northern Ireland, in having more anteriorly placed eyes and a less parallel-sided L2. *A.* cf. *truncatocaudata* (Owen 1986) from the High Mains Formation (Hirnantian) at Girvan, southwest Scotland, also has more posteriorly placed eyes than the Grangegeeth form. Two other Girvan species, *A. retardata* (Reed, 1914; Morris and Tripp 1986, p. 172, pl. 4, fig. 2) and *A. consobrina* Tripp, 1954, (p. 683, pl. 4, figs 26–33) from the Rawtheyan, and early Caradoc respectively, may be distinguished from *A. truncatocaudata* and the Grangegeeth form by their longer (exs.) eyes, and more parallel-sided L2 in *consobrina*. The Grangegeeth form differs from the type species (see Ludvigsen and Chatterton 1982) from the Shermanian and Edenian stages (late Caradoc – early Ashgill) of Canada and the USA, in its relatively longer (sag.) frontal glabellar lobe, more anteriorly placed eyes and larger number of lenses (twelve rather than seven) in the vertical rows.

Family LICHIDAE Hawle and Corda, 1847
Subfamily HOMOLICHINAE Phleger, 1936
Genus AUTOLOXOLICHAS Phleger, 1936

Type species. Lichas st. mathiae Schmidt, 1885, by original designation; from the Caradoc of Estonia.

Autoloxolichas cf. *laxatus* (M'Coy, 1846)

Text-fig. 5C

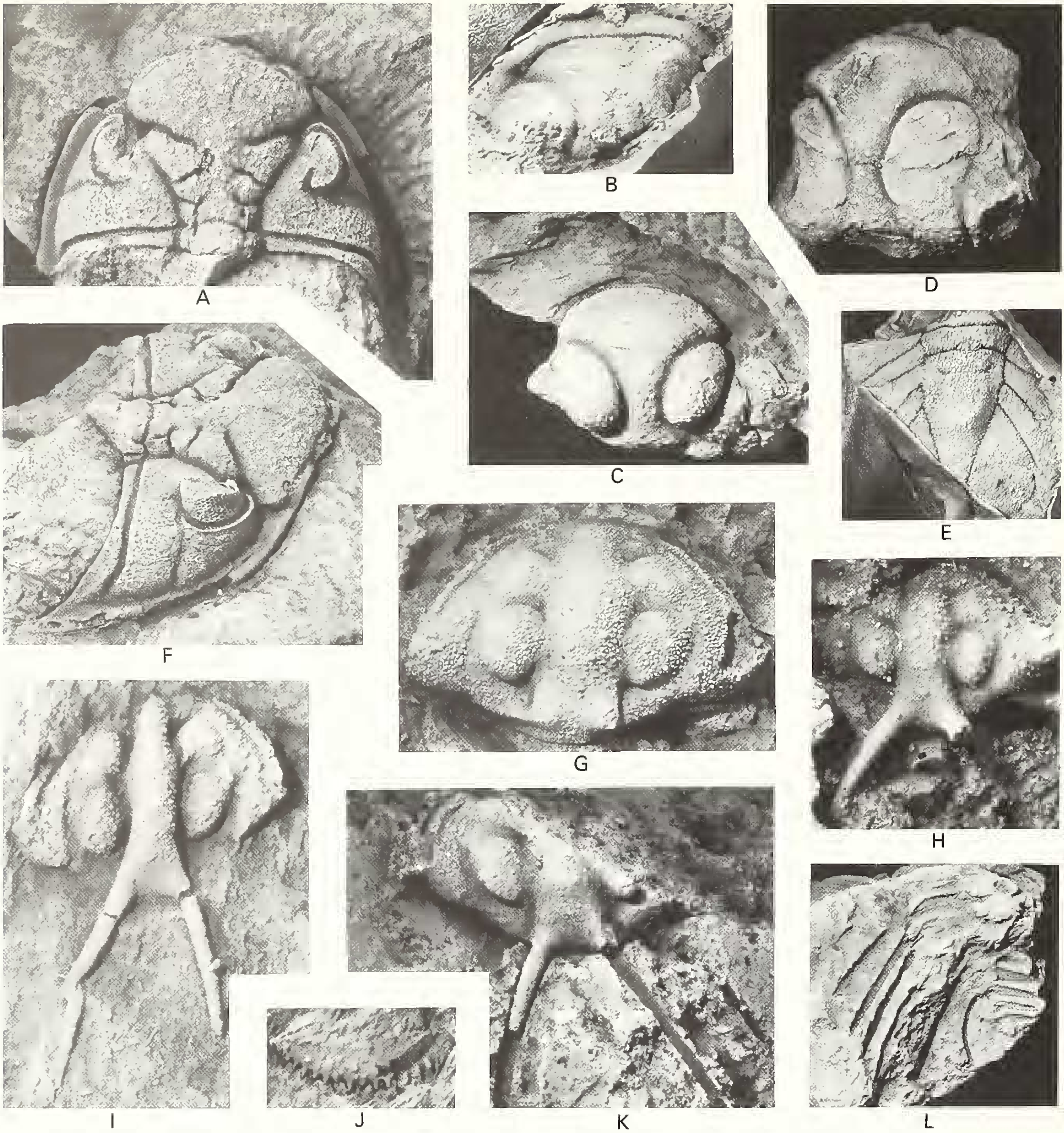
1967 *Platylichas laxatus* (M'Coy); Brenchley *et al.*, p. 298.
1980 *Platylichas* cf. *laxatus* (McCoy); Romano, p. 69.

Material. ?NMI F21015, NMI F21016 and fragmental specimens.

Horizon and locality. NMI F21016 from Loc. 209; other specimens from the Tretaspis Bed; Brickwork's Quarry.

Discussion. Thomas and Holloway (1988) assigned '*laxatus*' to *Autoloxolichas*. The Grangegeeth material shows diverging bullar lobes and quite strongly expanding median glabellar lobe, approaching the condition seen in *Platylichas* (see Thomas and Holloway 1988, p. 206). However the apparent suppression of L1b, relatively close proximity of bullar lobe and L1a, and shallow diffuse furrow joining these two lobes are characters regarded by Thomas and Holloway as typical of *Autoloxolichas*.

A. laxatus is a common species in the Caradoc of Britain, Ireland and Scandinavia. It commonly shows considerable variation (Dean 1963; Tripp 1958; Owen and Bruton 1980; Owen *et al.* 1986); in particular, as pointed out by Owen *et al.* (p. 115), in the relative size and shape of the bullar lobes, median glabellar lobe and anterior border. The present material differs from most of the previously figured specimens of this species in possessing a less strongly rounded anterior margin to the frontal glabellar lobe (cf. Tripp 1958, pl. 85, fig. 4; Dean 1963, pl. 43, figs 2, 10; Owen and



TEXT-FIG. 5. A, F, *Achatella truncatocaudata*? (Portlock, 1843). GSI F00880 (figured by Harper 1952, pl. 5, fig. 5 as GSI/JCH 529); basal Knockerk House Sandstones Member, Loc. 1; internal mould of cephalon, dorsal and lateral views respectively, both ×3. B, *Autoloxolichas* sp. indet. NMI F21015/B; Tretaspis Bed, Brickwork's Quarry Shales, Brickwork's Quarry; latex of external mould of incomplete cranidium, ×3. C, *Autoloxolichas* cf. *laxatus* (M'Coy, 1846). NMI F21016; Knockerk House Shales, Loc. 209; internal mould of incomplete cephalon, dorsal view, ×4. D–E *Amphilichas* sp.; D, NMI F21017; internal mould of incomplete cephalon, dorsal view, ×2. E, NMI F21018/B; cast of external mould of pygidium, dorsal view, ×1.5. Both from basal Knockerk House Sandstones Member, D from Collon Quarry, E from Loc. 3. G–L, *Miraspis* aff. *solitaria* Reed, 1935; G, NMI F21019; internal mould of cranidium, dorsal view, ×4; H, NMI F21020; cast of external mould of incomplete cranidium, dorsal view, ×7·5; I, NMI F14027 (figured by Harper 1952, pl. 5, fig. 4 as NMI 1951/13); cast of external mould of cranidium, dorsal view, ×7·5; J, NMI F21022; internal mould of free cheek, dorsal view, ×8; K, NMI F21023; internal mould of incomplete cranidium, dorsal view, ×6; L, NMI F21024; internal mould of part of thorax, dorsal view, ×3. G–H, J–K from concretions approximately 1 m above Tretaspis Bed, Brickwork's Quarry Shales, Brickwork's Quarry; I from ?Knockerk House Shales Member to basal Brickwork's Quarry Shales Member, Loc. 26. L from Tretaspis Bed.

Bruton 1980, pl. 10, figs 9–10, 13) and more rounded posterior margin to the bullar lobe (cf. Dean 1963, pl. 43, fig. 11; Owen and Bruton 1980, pl. 10, fig. 6; Owen *et al.* 1986, p. 113, fig. 77). However, Owen *et al.* (1986, figs 71–72) figured a cranidium assigned to *Platylichas laxatus* from the upper Caradoc Raheen Formation in Co. Waterford which is very similar to the present species.

A fragmentary, large cranidium (NMI F21015; Text-fig. 5B) has an estimated width across the front of the bullar lobes of 15 mm. The main features of this cranidium are the broadly rounded frontal glabellar lobe, the wide (sag. and trs.) border, deep and narrow anterior border furrow with small elongate lobe lying on inner part of border anterior to bullar lobe, wide and shallow lateral furrow and fine tuberculate sculpture. It is assigned to *Autoloxolichas* on account of its general characteristics and the presence of the small lobe lying anterior to the bullar lobe, a feature present in *A. nodulosus* (see Thomas and Holloway 1988, pl. 9, figs 188–189). It differs from *Autoloxolichas* cf. *laxatus* from the Knockerk House Shales Member in having a generally finer sculpture and it is considerably larger. It is provisionally referred to *Autoloxolichas* sp. indet.

Subfamily TETRALICHINAE Phleger, 1936
Genus AMPHILICHAS Raymond, 1905

Type species. Platymetopus lineatus Angelin, 1854, by monotypy; from the Boda Limestone (Ashgill) in Dalarna, Sweden.

Amphilichas sp.

Text-fig. 5D–E

1952 *Lichas* (*Acrolichas*) *hibernicus* (Portlock); Harper, p. 88
1980 *Amphilichas hibernicus* (Portlock); Romano, p. 66.
1980 *Amphilichas* cf. *ardmillanensis* (Reed); Romano, p. 67.

Material. NMI F21017–F21018.

Horizon and locality. NMI F21017 from Collon Quarry; NMI F21018 from Loc. 3.

Discussion. At present, it is not known whether the material from Collon (cranidium) is conspecific with that from Grangegeeth (segment and pygidium), even though they occur at a similar horizon. As far as the authors are aware, no pygidium of *A. ardmillanensis* has been figured. The cranidium differs from *A. ardmillanensis* (Reed, 1914; Tripp 1958, 1980) from the Upper Balclatchie and Lower Ardwell groups (lower Caradoc), Girvan, southwest Scotland in the following respects: the anterior margin of the central lobe is a smooth curve with no subconical projection in the middle; the median lobe expands (trs.) posteriorly; the furrows posterior to the composite lateral lobes are fainter; the anterior border is steeply declined. However, the Irish specimen is deformed, which may account for some of these differences. Faint posterolateral glabellar furrows are also seen in other Balclatchie Group species, *A. panoplos* and *A. planus* (Tripp 1980, pl. 4, fig. 17; Tripp 1954, pl. 1, fig. 5, respectively), but the median glabellar lobe is wider in the two Scottish species. Discontinuous lateral furrows are seen in *A.* sp. B (Tripp 1976, pl. 7, fig. 23) from the Superstes Mudstones at Girvan but, this species has a more strongly rounded glabellar outline.

The Irish pygidium differs only slightly from that of *A. hibernicus* from the Lower Ardwell Group at Girvan figured by Reed (1914) and Thomas and Holloway (1988, pl. 12, fig. 256). The axis of the Irish specimen narrows less rapidly posteriorly and consists of a flatter portion reaching back to the anterior part of the third segment where it then slopes down sharply to the near horizontal terminal piece (compare Thomas and Holloway 1988, pl. 12, fig. 261). The oblique and incomplete second axial ring furrows are larger in the Scottish specimen and the sculpture of the Irish pygidium is slightly coarser. The doublure is broad in the Irish specimen and, as in *A. hibernicus*, reaches the distal ends of the pleural furrows.

lichid indet.

1980 Lichid indet.; Romano, p. 67.

Material. BM It.25736*a*–*b*.

Horizon and locality. Collon Quarry.

Discussion. The material is fragmentary, but a comparison may be made with *Metopolichas*? (Dean 1963, pl. 43, fig. 4) from the Costonian of Shropshire, England. It differs from Dean's species in having a coarser sculpture on the frontal lobe. Thomas and Holloway (1988) pointed out the uncertainty of the status of *Metopolichas*, but placed it in the Homolichinae on account of the form of the hypostoma. On cranidial characteristics these authors noted that *Metopolichas* is very similar to *Lichas*, thus casting further doubt on the generic assignment of the Knockerk Sandstone specimen. A cranidium of *Amphilichas* sp. occurs at a similar horizon at Grangegeeth (see above), but this species has a considerably more rounded anterior margin.

Family ODONTOPLEURIDAE Burmeister, 1843
Subfamily SELENOPELTINAE Hawle and Corda, 1847
(= MIRASPIDINAE Richter and Richter, 1917; DICRANURIDAE Prantl and Přibyl, 1949: see Ramsköld 1991)
Genus MIRASPIS Richter and Richter, 1917

Type species. *Odontopleura mira* Barrande, 1846, by original designation; from the Liteň Formation (Wenlock), near Beroun, Bohemia.

Miraspis aff. *solitaria* Reed, 1935

Text-fig. 5G–L

1952 *Acidaspis* (*Onchaspis*) cf. *lalage* Wyville Thomson; Harper, pp. 89, 105, pl. 5, fig. 4.
1967 *Diacanthaspis* sp. cf. *D. lalage* (Wyville Thomson); Brenchley *et al*., p. 298.
1980 *Miraspis* sp.; Romano, pp. 69–70.

Material. NMI F14027 (figured Harper 1952, pl. 5, fig. 4 as NMI 1951/13); NMI F21019, F21020, F21022–24; BM It.25737–It.25740.

Horizon and locality. NMI F14027 from Loc. 26; others from Tretaspis Bed and concretions 1 m higher, Brickwork's Quarry.

Discussion. *Miraspis solitaria* (Reed 1935, p. 37, pl. 3, fig. 21) is from the basal Superstes Mudstones (Llandeilo) at Aldons Quarry, Girvan, and was redescribed by Tripp (1976, p. 412, pl. 7, figs 27–32). The Grangegeeth form shows minor differences on the free cheek, where its border and furrow are more distinct, the granulation on the cranidium is finer, and the marginal spines are not directed as obliquely. Until a pygidium is known from Grangegeeth some doubt must remain as to whether the material does belong in *M. solitaria*.

Owen and Romano (*in* Harper *et al*. 1985, p. 306) distinguished the Grangegeeth *Miraspis* from an unnamed Caradoc species from the Clashford House Formation near Herbertstown, Co. Meath, eastern Ireland, on the basis of its more slender occipital spines, more circular L1 and weaker furrows at the side of the median glabellar lobe. The last two of these also distinguish the Grangegeeth form from *Miraspis* sp. of Owen *et al*. (1986; see also Ramsköld 1991, p. 171) from the upper Caradoc Raheen Formation in Co. Wexford, which also lacks a median occipital protuberance but, like the other Irish species, has a very weakly incised occipital furrow.

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M. ROMANO

Department of Earth Sciences
University of Sheffield
Dainton Building, Brookhill
Sheffield S3 7HF, UK

A. W. OWEN

Department of Geology and Applied Geology
Lilybank Gardens
University of Glasgow
Glasgow G12 8QQ, UK

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